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A STUDY OF VAPOR CONTROL METHODS FOR GASOLINE MARKETING OPERATIONS.

VOLUME I. INDUSTRY SURVEY AND CONTROL TECHNIQUES

RADIAN CORPORATION

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

APRIL 1975

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A STUDY OF VAPOR CONTROL METHODS FOR GASOLINE MARKETING OPERATIONS: VOLUME I - INDUSTRY SURVEY AND CONTROL TECHNIQUES

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Background information is given on the size and extent of the gasoline marketing industry and the magnitude of hydrocarbon vapor emissions. The principal sources of emissions, tank truck filling at bulk terminals, service station storage tank filling and vehicle refueling are characterized. Vapor control techniques for bulk terminals are described: compression, refrigeration, absorption, adsorption, incineration, and combinations of these techniques. The two types of control systems for service stations are evaluated, vapor balance systems and vacuum assist/secondary processing systems. Test data are given.

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by

C.E. Burklin, E.C. Cavanaugh,
J.C. Dickerman, and S.R. Fernandes

Radian Corporation
8500 Shoal Creek Boulevard
Austin, Texas 78766

Contract No. 68-02-1319

EPA Project Officer: Edwin J. Vincent

Prepared for

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Office of Air Quality Planning and Standards
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April 1975

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INTRODUCTION

The purpose of this report is to provide the Environmental Protection Agency with information relative to hydrocarbon emission sources in the gasoline marketing industry.

This report contains information on the size of and growth trends within the industry, the extent and nature of its hydrocarbon emissions, and the status of existing and developing emission control technology.

Additional work is required in the evaluation of hydrocarbon emissions from the gasoline marketing industry. This work involves re-evaluation of test procedures and further investigation of the impacts of various control alternatives. Recommended additional work and a discussion of unresolved issues are included in the report.

1.0 SUMMARY

1.1 Report Objectives

It is the policy of the Environmental Protection Agency, prior to issuing documents leading to emissions regulations or for emissions guidelines, to make every effort to examine carefully the impacts of such documents on citizens, industry, and government. The approach is to gain broad knowledge of the industry in question; its size, type of facilities, growth patterns, and history with regard to pollution. Of interest also are regulations, pending or in force, that have an impact on the industry, on its customers and employees, or on any citizen or organization that might be affected. The objective of this report is to provide to EPA technical information relating to hydrocarbon emission from gasoline marketing facilities and to the methods of controlling these emissions.

1.1.1 Regulations

Regulation of hydrocarbon emissions from gasoline marketing operations is being examined by EPA for both existing and new facilities. Although the emission control equipment and the marketing facilities proper are basically identical, there are notable differences in emission control objectives for the two cases.

Sections 108, 109, and 110 of the Clean Air Act Amendments of 1970 apply to existing sources. In these sections it is stated that the Administrator of the EPA has authority, after identifying air pollutant sources, and establishing regulations prescribing national standards for these pollutants, to require that implementation plans be provided by states where control of such emissions might be required.

Federal standards of performance for new stationary sources will be considered under Section 111 of the Act which requires that standards of performance reflect the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated.

Achieving the national ambient air quality standard for hydrocarbons (maximum three-hour concentration of 160 $\mu g/m^3$, not to be exceeded more than once per year) may require gasoline vapor emission control at existing facilities in various segments of the nation. Some air pollution control districts, however, may require no emission controls at existing gasoline handling facilities, depending on the nature and intensity of hydrocarbon emissions from other sources in that district.

Upon promulgation of new source standards of performance, those facilities identified as new sources or those modified such as to substantially increase emissions from existing sources will be subject to control such that new pollutants added to the air are held to the minimum possible or practical amount.

1.1.2 Control Technology

Hydrocarbon emission control technology at service stations, bulk plants, and terminals today is that involved with control at existing facilities. In many cases, the equipment in use is quite new and not fully performance tested. Furthermore, while these recovery systems may be adequate for control of existing facilities, control regulations for new sources may require higher overall collection efficiencies.

This report, therefore, includes the results of investigation of all aspects of hydrocarbon emission in the gasoline marketing industry. This includes analysis of performance tests on existing control units at service stations and terminals. It also includes engineering assessment of these units on a theoretical basis, evaluation of their capital and operating costs, consideration of their reliability and safety of operation; all based on information supplied by equipment suppliers and industry users.

Because many segments of the control technology are in their infancy, it is essential that well considered projections are made to assess ultimate methods of achieving "best" practical control. One example is anticipated improvements in mechanical design of the nozzle-fill pipe interface for vehicle refueling. Any major improvement of this equipment if achieved nationwide, would have considerable bearing on determining the "best" approach to effective containment of gasoline vapor emissions.

1.1.3 Statistics

The gasoline marketing network is large and complex. Its activities affect a large percentage of the citizenry on a day-to-day basis. Certain sections of this report are intended to provide EPA with helpful background information on the industry. Included are statistical data (number of stations and terminals, gallons sold, growth patterns, and so on) and commentary (anticipated reactions, alternative technology, status of regulations, and so on).

1.2 Conclusions and Comments

The following comments are presented to summarize the status of the principal issues involved in the evaluation of control technology for both new and existing gasoline marketing facilities. Considerable work remains to be done in the evaluation of hydrocarbon emission control systems. Some of this work involves field testing to substantiate equipment performance at marketing locations. Other work involves investigation of issues described in the following paragraphs.

(1) At service stations 90 percent control or better of emission resulting from underground tank failure operations can be achieved using known technology. This essentially involves using a balance system with submerged fill for fuel drops.

(2) For Stage II controls it appears that 80 percent control can be achieved with a balance system, assuming a reasonably good nozzle-fill pipe interface. Using vacuum assist with reasonably good fit at the nozzle, a 90 percent control looks possible. This assumes, however, that the secondary recovery equipment can be operated in a safe and reliable fashion.

(3) There has been little industrial experience demonstrating reliable stream factors with the vacuum assist units. This equipment is, however, in an early period of development. Similar types of equipment in industrial and commercial use have histories of highly reliable operation.

(4) The costs to install recovery systems at new service stations are estimated to be $3000 for balance systems, and $10,000 for vacuum assist systems, both based on installation at a typical 32,000 gallon per month station. For an existing station the costs are estimated to be $6000 for balance systems and $13,000 for vacuum assist systems.

(5) The population of retail gasoline outlets is changing. The total number of service stations in the nation has decreased over the past two years. Small to medium size stations are being phased out. New stations being built are generally in the larger category (50,000 to 150,000 gallons per month). Many convenience store and self service outlets ranging in size from very small (2000 gallons per month) to very large (150,000 gallons per month) are also among the new installations.

(6) For very small retail outlets, particularly in rural areas, the use of vacuum assist adds substantially to capital and operating costs, while providing only a marginal benefit in terms of pollution control.

(7) Meaningful comparisons of vacuum assist and vapor balance systems are difficult because of testing procedure inadequacies.

(8) Resolution of the nozzle-fill pipe closure problem will require the contributions of automobile manufacturers, gasoline marketers, nozzle manufacturers, and government agencies.

(9) There has been a steady decline in the number of bulk stations in the nation. Many more such stations are marginal operations and probably will be closed, or at least not expanded, in the years ahead. There will undoubtedly be the need for a limited number of new bulk stations in certain rural areas, however.

(10) Control technology used in either bulk terminals or service stations appears to be directly applicable to bulk stations.

(11) Vapor control systems have been in use at bulk terminals for two decades. The technology is, therefore, well established. New and improved designs are being made commercially available, however.

(12) Marine terminals have not been subject to vapor control in the past; however, this situation may change. Control technology used at bulk terminals should be directly applicable at marine loading facilities.

(13) The actual impact of gasoline vapor emissions nationwide has not been quantified. While certain urban areas have experienced pronounced

1.2 Conclusions and Comments (cont.)

adverse effects because of the conversion of these emissions to photochemical oxidants, the impacts on many rural regions have not been characterized.

(14) Regulations governing hydrocarbon emissions from gasoline marketing operations may be promulgated on three bases: percent reduction, mass emissions, and equipment standards. A regulation based on mass emissions has advantages in that it is applicable to all vapor recovery systems and is not affected by seasonal variations.

2.0 TECHNICAL DISCUSSION

Technical information and evaluations of many aspects of both hydrocarbon emissions and hydrocarbon recovery from the gasoline marketing industry are contained in this section of the report. The following discussion presents brief descriptions of each subsection.

Section 2.1 contains a description of the domestic gasoline industry, including the number and locations of plants and facilities, product rates and values, growth trends, and number of people employed by and served by the industry. The current status of regulations and transportation control plans covering control at certain existing marketing facilities is given. Descriptions of equipment and support facilities in terminals, bulk stations, and service stations are provided. The nature, extent and impact of hydrocarbon emissions from these facilities are described.

The available control systems in use or under development are discussed in Section 2.2, with regard to operating principles, and histories of control efficiency, mechanical performance, reliability, and general applicability to the primary emission sources. Descriptive sketches are provided.

For terminals and service stations numerous control systems are available commercially. Control at bulk stations has had limited application in the nation; however, technology developed for terminals and service stations appears to be totally applicable. Gasoline handling operations at marine terminals is also subject to technology transfer according to manufacturers supplying equipment and fittings to that industry.

The impact on air pollution of these control systems is described in Section 2.3. These impacts are defined as mass emission reductions at each source. The factors being considered in state transportation control plans regarding reduction in ambient air concentrations are discussed. Impacts on other pollution forms such as water or solid waste are negligible for these systems.

There are several issues concerning hydrocarbon emissions from the gasoline marketing industry which were unresolved at the time this report was drafted. These issues are discussed in Section 2.4. With regard to emissions control at gasoline marketing facilities, unresolved issues are primarily differences of opinion with no one opinion fully supported by fact.

Some facts, such as efficiencies or costs of vapor recovery units, can be obtained through source tests or through recorded capital or operating costs. Other data, such as operating reliability of newly developed systems, may not be subject to immediate proof, but might yield to judgment based on analogous experience. Each unresolved issue described in this section is examined with the purpose of deciding where facts are needed and if so, how they should be obtained. Where judgment is the principal requirement, this is so defined.

Finally, a discussion of areas in which Radian feels additional work is necessary to be able to fully evaluate the impact of hydrocarbon emissions and controls from the gasoline marketing industry is presented in Section 2.5. Some of these areas of work may be under current study, however, all should be investigated to fully resolve the issues.

2.1 Gasoline Marketing Industry

2.1.1 Background

The gasoline marketing industry is defined as that industry concerned with the transfer and storage of gasoline. This definition includes the loading of gasoline into tank trucks and/or tank cars at petroleum refineries and marketing terminals, the unloading of gasoline into storage tanks at service stations, and, finally, the loading of gasoline into vehicle tanks. These operations represent a significant part of the petroleum industry.

2.1.1.1 Size and Extent of the Industry

In 1967, over 80 billion gallons per year were distributed through 2,700 marketing terminals and over 36,000 bulk stations. By 1973 annual U.S. consumption had grown to over 106 billion gallons, about 70 percent of which was sold to passenger cars at 212,000 retail service stations. The remaining 30 billion gallons were sold to industrial, commercial, and rural customers or to passenger cars at nonservice station outlets. The combined wholesale and retail segments of the gasoline marketing industry employ 700,000 people.

U.S. Gasoline Production

In 1973, 261 refineries in 38 states produced 6.7 million barrels per day of gasoline. Table 2.1-1 specifies the number of refineries and the volume of gasoline produced in each state. Outputs from these refineries, plus some imported refined products, are the sources of supply to the domestic gasoline marketing network.

TABLE 2.1-1

GASOLINE REFINING AND MARKETING FACILITIES

State	Refineries[1]	Gasoline Output(b/d)[1]	Bulk Stations[2]	Terminals[2]	Bulk Stations and Terminals		Service Stations
	1973	1973	1967	1967	1967[2]	1972[3]*	1972[4]
Alabama	4	1,200	449	52	501	518	4,510
Alaska	2	----	29	50	79	88	241
Arizona	1	----	213	17	230	219	2,357
Arkansas	4	16,700	526	24	550	535	3,144
California	37	1,009,479	1,154	125	1,279	1,166	19,153
Colorado	3	30,550	----	---	452	366	3,170
Connecticut	0	----	72	60	132	120	2,798
Delaware	1	73,400	34	10	44	43	557
D.C.	0	----	4	3	7	7	318
Florida	1	----	546	79	625	558	9,199
Georgia	2	----	610	63	673	656	6,730
Hawaii	1	11,680	12	30	42	32	480
Idaho	0	----	366	23	389	317	1,193
Illinois	12	592,950	1,448	85	1,533	1,324	10,211
Indiana	7	219,095	993	74	1,067	865	6,235
Iowa	0	----	1,481	49	1,530	1,202	4,484
Kansas	10	190,271	841	26	867	663	3,609
Kentucky	4	59,400	492	44	536	417	3,921
Louisiana	20	788,330	464	58	522	569	3,921
Maine	0	----	142	34	176	163	1,224
Maryland	2	----	129	58	187	172	3,012
Massachusetts	0	----	112	49	161	157	4,698
Michigan	6	57,320	1,055	87	1,142	1,023	8,919
Minnesota	3	69,910	1,282	43	1,325	1,012	4,585

TABLE 2.1-1 (Cont.)

GASOLINE REFINING AND MARKETING FACILITIES

State	Refineries[1] 1973	Gasoline Output (b/d)[1] 1973	Bulk Stations[2] 1967	Terminals[2] 1967	Bulk Stations and Terminals 1967[2]	Bulk Stations and Terminals 1972[3]*	Service Stations 1972[4]
Mississippi	5	161,400	448	35	483	427	2,725
Missouri	1	38,400	1,028	55	1,083	839	6,280
Montana	8	68,326	----	---	418	356	1,190
Nebraska	1	2,200	589	19	608	471	2,265
Nevada	0	----	89	12	101	90	798
New Hampshire	0	----	69	7	76	70	888
New Jersey	5	237,970	147	89	236	218	5,768
New Mexico	6	18,150	230	17	247	246	1,831
New York	2	42,100	481	282	763	672	11,359
N. Carolina	0	----	732	114	846	771	6,946
N. Dakota	2	22,000	634	14	648	556	910
Ohio	7	292,090	905	118	1,023	784	11,723
Oklahoma	12	253,417	589	25	614	594	4,153
Oregon	1	----	504	28	532	434	2,828
Pennsylvania	11	330,435	603	156	759	662	11,256
Rhode Island	1	----	27	17	44	36	901
S. Carolina	0	----	368	46	414	378	3,720
S. Dakota	0	----	531	16	547	491	1,171
Tennessee	0	14,000	439	53	492	439	5,157
Texas	43	1,795,075	1,841	118	1,959	2,211	17,118
Utah	6	53,400	164	11	175	155	1,504
Vermont	0	----	61	11	72	60	596
Virginia	1	24,000	447	87	534	473	4,648
Washington	6	161,770	579	94	673	541	3,945
W. Virginia	3	5,650	160	29	189	162	2,156

TABLE 2.1-1 (Cont.)

GASOLINE REFINING AND MARKETING FACILITIES

State	Refineries[1] 1973	Output(b/d)[1] 1973	Bulk Stations[2] 1967	Terminals[2] 1967	# Bulk Stations and Terminals 1967[2]	# Bulk Stations and Terminals 1972[3]*	Service Stations 1972[4]
Wisconsin	1	14,100	1,222	71	1,293	1,042	5,182
Wyoming	9	67,140	----	---	192	161	772
TOTAL	252	6,722,108	26,338	2,701	29,039	25,531	226,459

Source: *This complete list of figures has not been publicly released. The Social and Economic Statistics Administration, Bureau of the Census has specified that they not be released by EPA until they are publicly released.

[1] API Annual Statistical Review, Petroleum Industry Statistics, 1964-73, p. 33.(AM-099)

[2] 1967 Census of Business, Vol. 3, Wholesale Subject Reports. (US-031)

[3] 1972 Census of Business, Wholesale Trade, Area Statistics.

[4] 1972 Census of Business, Retail Trade, Area Statistics

2.1.1.1 Size and Extent of the Industry (Cont.)

U.S. Gasoline Consumption

In 1973, U.S. consumption of gasoline was 106 billion gallons, a 4.7 percent increase over 1972 consumption. As indicated in Figure 2.1-1, the number of gallons of gasoline consumed annually between 1968 and 1973 has increased steadily with an average annual increase of 5.2%. This increase may be attributed to two factors: (1) an increase in the number of vehicles on the road, and (2) a gradual increase in the number of miles traveled per vehicle combined with an accompanying decrease in the number of miles achieved per gallon through 1973 model automobiles.

America, a mobile society, has become increasingly more dependent on the automobile as a means of transportation in the last two decades. This trend is demonstrated by the steady growth in annual consumption of energy by automobiles as compared with a comparable decrease in energy consumption by public transportation (CI-005). Current statistics reflect that eight out of ten American households own at least one car and three out of ten own two cars (FO-027).

Roughly 13 million new drivers have been registered and 17 million motor vehicles have been added to U.S. roads since 1969. A state-by-state breakdown of these figures as compared with gasoline consumption is given in Table 2.1-2.

In addition to increased dependence on the automobile, gasoline demand has been affected by a loss of fuel economy in recent years. In 1963, the average passenger car got 14.4 miles per gallon; in 1973 this figure was estimated to be 13.3 miles per gallon (NA-168). This decrease in fuel efficiency has been attributed to the increased weight of automobiles, the increased

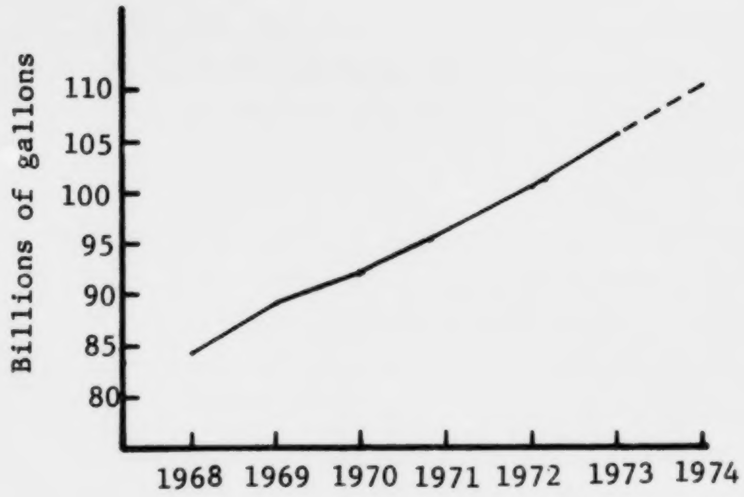

FIGURE 2.1-1 - U.S. GASOLINE CONSUMPTION

Source: NPN Mid-May Factbook, 1968-74.

TABLE 2.1-2

GASOLINE CONSUMPTION BY STATE

STATE	POPULATION[1]	REGISTERED MOTOR VEHICLES[2]			GASOLINE CONSUMPTION[2] Add 000 gal.		
	1972	1972	1973 (estimated)	% Increase	1972	1973	% Increase
ALABAMA	3,510,000	2,227,293	2,363,000	6.1	1,811,609	1,901,914	5.0
ALASKA	325,000	148,756	161,000	8.2	122,639	135,754	10.7
ARIZONA	1,945,000	1,301,870	1,418,000	8.9	1,105,586	1,211,826	9.6
ARKANSAS	1,978,000	1,070,295	1,096,000	2.4	1,175,865	1,124,473	4.6
CALIFORNIA	20,468,000	12,852,228	13,445,000	4.6	10,128,458	10,425,236	2.9
COLORADO	2,357,000	1,679,70[illegible]	1,805,000	7.5	1,300,450	1,362,836	4.8
CONNECTICUT	3,082,000	1,860,385	1,939,000	4.2	1,336,043	1,359,316	1.7
DELAWARE	565,000	322,971	341,000	5.6	292,733	308,648	5.4
DISTRICT OF COLUMBIA	748,000	259,492	252,000	-2.9	243,253	259,339	6.6
FLORIDA	7,259,000	4,835,986	5,131,000	6.1	3,956,142	4,379,689	10.7
GEORGIA	4,720,000	2,959,454	3,157,000	6.7	2,688,489	3,082,334	14.6
HAWAII	809,000	447,409	473,000	5.7	267,245	276,736	3.6
IDAHO	756,000	549,834	596,000	8.4	463,143	481,714	4.0
ILLINOIS	11,251,000	5,643,853	5,867,000	4.0	4,852,112	5,063,378	4.4
INDIANA	5,244,000	2,908,543	2,959,000	1.7	2,767,014	2,867,475	3.6
IOWA	2,883,000	1,917,075	1,985,000	3.5	1,673,848	1,821,011	8.8
KANSAS	2,257,000	1,691,501	1,818,000	7.5	1,450,625	1,433,253	-1.2
KENTUCKY	3,299,000	1,967,620	2,106,000	7.0	1,633,516	1,760,172	7.8
LOUISIANA	3,693,000	1,942,263	2,069,000	6.5	1,704,022	1,793,721	5.3

TABLE 2.1-2 (Cont.)

GASOLINE CONSUMPTION BY STATE

	POPULATION[1]	REGISTERED MOTOR VEHICLES[2]			GASOLINE CONSUMPTION[2] Add 000 gal.		
STATE	1972	1972	1973 (estimated)	% Increase	1972	1973	% Increase
MAINE	1,029,000	564,782	582,000	3.0	525,300	543,737	3.5
MARYLAND	4,056,000	2,130,458	2,272,000	6.6	1,785,969	1,852,382	3.7
MASSACHUSETTS	5,787,000	2,821,596	2,944,000	4.3	2,290,313	2,360,033	3.0
MICHIGAN	9,082,000	5,010,537	5,187,000	3.5	4,585,129	4,774,714	4.1
MINNESOTA	3,860,000	2,368,127	2,499,000	5.5	2,109,913	2,155,860	2.2
MISSISSIPPI	2,250,000	1,249,152	1,313,000	5.1	1,204,810	1,237,932	2.7
MISSOURI	4,753,000	2,618,164	2,719,000	3.9	2,667,902	2,742,295	2.8
MONTANA	719,000	584,116	652,000	11.6	457,792	474,804	3.7
NEBRASKA	1,525,000	1,080,885	1,141,000	5.6	917,215	936,994	2.2
NEVADA	527,000	399,046	428,000	7.3	374,164	390,979	4.5
NEW HAMPSHIRE	771,000	436,158	468,000	7.3	393,322	405,147	3.0
NEW JERSEY	7,367,000	3,858,631	4,094,000	6.1	3,188,965	3,266,842	2.4
NEW MEXICO	1,065,000	710,765	758,000	6.6	660,638	702,265	6.3
NEW YORK	18,366,000	7,006,452	7,113,000	1.5	6,056,144	6,318,982	4.3
N. CAROLINA	5,214,000	3,219,776	3,456,000	7.3	2,767,481	2,874,027	3.8
N. DAKOTA	632,000	463,622	489,000	5.5	429,682	436,977	1.7
OHIO	10,739,000	6,224,278	6,359,000	2.2	4,982,198	5,286,197	6.1
OKLAHOMA	2,634,000	1,887,210	1,978,000	4.8	1,666,744	1,729,329	3.8
OREGON	2,182,000	1,496,115	1,619,000	8.2	1,198,744	1,247,483	4.1

TABLE 2.1-2 (Cont.)
GASOLINE CONSUMPTION BY STATE

STATE	POPULATION[1]	REGISTERED MOTOR VEHICLES[2]			GASOLINE CONSUMPTION[2] Add 000 gal.		
	1972	1972	1973 (estimated)	% Increase	1972	1973	% Increase
PENNSYLVANIA	11,926,000	6,311,330	6,655,000	5.4	4,811,065	4,874,664	1.3
RHODE ISLAND	968,000	536,284	566,000	5.5	413,405	415,762	.6
S. CAROLINA	2,665,000	1,497,389	1,608,000	7.4	1,412,207	1,478,414	4.7
S. DAKOTA	679,000	462,613	484,000	4.6	470,521	479,785	2.0
TENNESSEE	4,031,000	2,293,635	2,439,000	6.3	2,129,984	2,296,340	7.8
TEXAS	11,649,000	7,315,711	7,708,000	5.4	7,093,777	7,497,154	5.7
UTAH	1,126,000	740,507	789,000	6.5	689,037	706,166	2.5
VERMONT	462,000	261,295	273,000	4.5	243,508	246,285	1.1
VIRGINIA	4,764,000	2,602,773	2,815,000	8.2	2,409,315	2,611,693	8.4
WASHINGTON	3,443,000	2,242,060	2,379,000	6.1	1,648,222	1,730,908	5.0
W. VIRGINIA	1,781,000	873,606	919,000	5.2	736,772	778,359	5.6
WISCONSIN	4,520,000	2,378,836	2,500,000	5.1	2,212,202	2,155,014	2.7
WYOMING	345,000	273,608	291,000	6.4	288,912	309,244	7.0
U.S. TOTAL	208,232,000	118,506,048	124,478,000	5.0	101,685,524	106,474,172	4.7

SOURCES: [1] Statistical Abstract of the U.S., Table 13, "Population-States: 1960-1972".

[2] NPN Mid-May Factbook, 1974. (NA-168).

prevalence of accessory items such as air conditioning, power steering, automatic transmissions, and emission control devices on post-1970 model cars. Efforts are now being made by car manufacturers to reverse this trend. The use of the catalytic converter as an emission control device will add to the number of miles per gallon. It is estimated that 80-85% of 1975 model cars will be equipped with catalytic converters (AA-007). General Motors is predicting a 20% increase in fuel economy on 1975 models equipped with this device. It will not be possible to assess the impact of catalytic converters on overall gasoline consumption, however, until mid-1975 (AA-007). Other fuel economy measures would include an increased production of lighter cars and cars with smaller engines.

The increase in the average number of gallons consumed by passenger cars between 1969 and 1973 is indicated in Table 2.1-3. An increase in the average number of miles traveled is also shown. Fuel efficiency for cargo vehicles has remained relatively constant.

2.1.1.2 The Gasoline Marketing Network

Figure 2.1-2 shows the basic flow of gasoline from refinery storage to the vehicle refueling stations in the U.S. marketing network.

Gasoline is transported from refinery storage to terminals by pipelines, tankers and barges, or rail tank cars. In 1967, 42% of the U.S. terminals reported receiving bulk liquid products by barge and 35% by pipeline (US-031).

The same statistics show that approximately 80% of the bulk stations received their products by tank truck (US-031).

TABLE 2.1-3

AVERAGE FUEL CONSUMPTION 1969-1973

	AVERAGE MILES TRAVELED/ VEHICLE		AVERAGE FUEL CON- SUMPTION/VEHICLE		AVERAGE MILES/ GALLON OF FUEL	
	Passenger Cars	All Vehicles	Passenger Cars	All Vehicles	Passenger Cars	All Vehicles
1969	9,782	9,969	718	821	13.6	12.15
1970	9,978	10,076	735	830	13.6	12.14
1971	10,121	10,198	746	838	13.6	12.16
1972	10,184	10,370	755	859	13.5	12.07
1973	10,184	10,370	766	864	13.3	12.07

SOURCE: U.S. Dept. of Transportation, Federal Highway Administration, Highway Statistics, 1969-72; 1973 - NPN Mid-May Factbook, 1974, (NA-168), and Radian estimates.

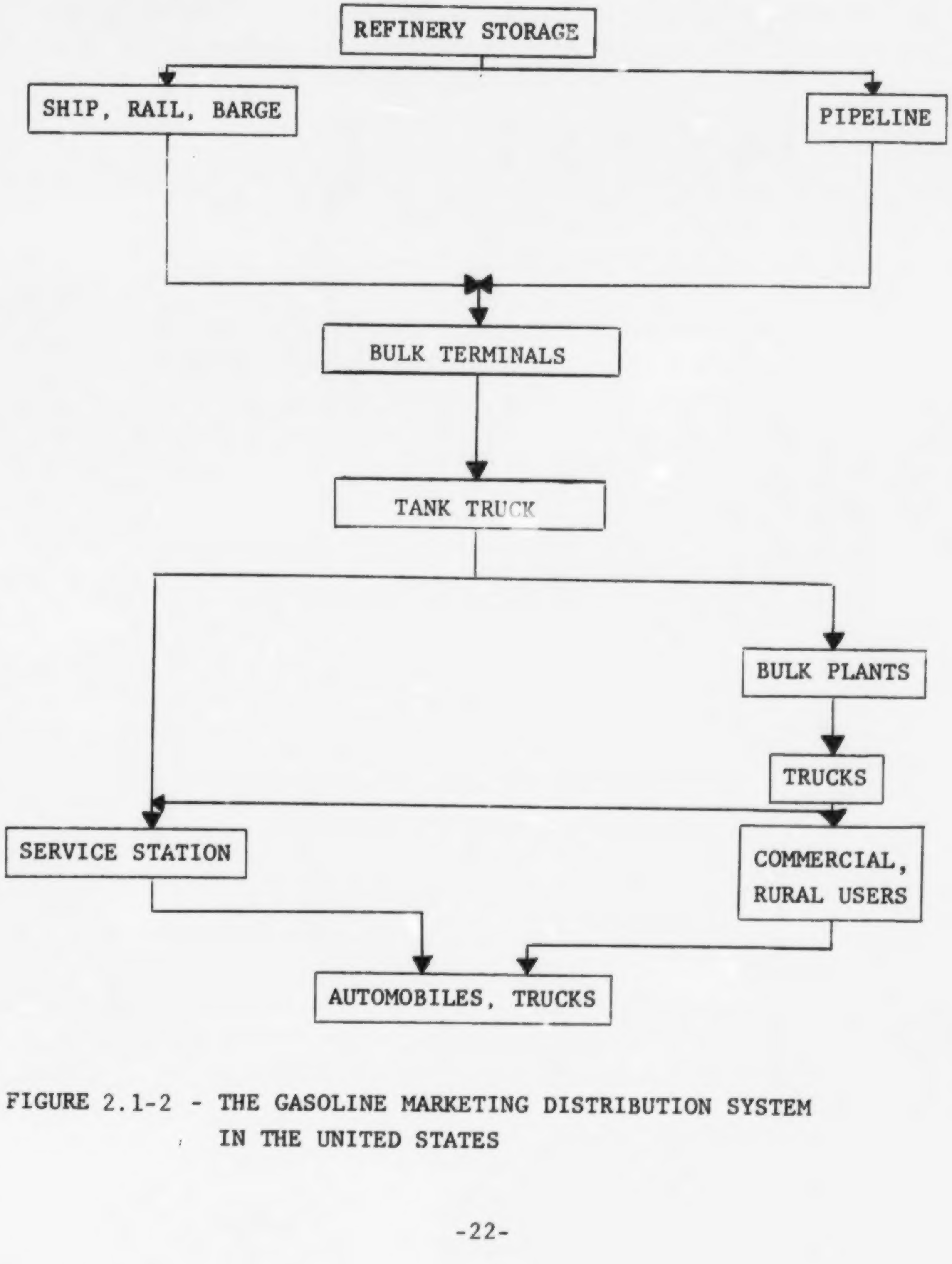
REFINERY STORAGE
SHIP, RAIL, BARGE
PIPELINE
BULK TERMINALS
TANK TRUCK
BULK PLANTS
TRUCKS
SERVICE STATION
COMMERCIAL, RURAL USERS
AUTOMOBILES, TRUCKS

FIGURE 2.1-2 - THE GASOLINE MARKETING DISTRIBUTION SYSTEM IN THE UNITED STATES

2.1.1.2 The Gasoline Marketing Network (Cont.)

Bulk stations are intermediate distribution points in the marketing network. Gasoline from the 8,000-gallon trucks is unloaded into storage tanks at the bulk stations, then reloaded into smaller tank trucks, usually in the 2,000-gallon category, for distribution to service stations and to commercial and rural users. In many areas, gasoline is delivered directly from terminals to service stations. Table 2.1-1 lists the number of wholesale marketing facilities in each state. Gasoline is unloaded into underground storage tanks at the more than 300,000 domestic service stations and other gasoline retail outlets.* Table 2.1-1 lists the number of service stations in each state. Sizes of service stations vary widely, from 5,000 to 500,000 gallons per month of gasoline dispensed. Average service station size is about 30,000 gallons per month. Other gasoline retail outlets range from 2,000-3,000 gallons per month to as much as 150,000 gallons per month.

Sizes and trends for marketing terminals and retail outlets are described in more detail in the following sections.

Marketing Companies

There are over 400 oil companies involved in some aspect of the U.S. gasoline marketing network according to a 1974 NPN listing (NA-168). Table 2.1-4 lists those oil companies whose activities accounted for 0.13 percent or more of the market in 1973. For statistical purposes, these companies have been divided into six categories: integrated marketers, other

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* A service station is defined as a retail outlet with more than 50% of its dollar value coming from the sale and service of petroleum products. Retail outlets not meeting this definition are grouped together as "other gasoline retail outlets" or "nonservice station" outlets.

TABLE 2.1-4

1973 OIL COMPANY MARKETING STATISTICS*

Company Name	Home Office	Gasoline Sales (add 000 gal.) 1973	% Change	Bulk Plants	Terminals	Service Stations**	Total Branded Retail Outlets
INTEGRATED MARKETERS							
Texaco	N.Y., N.Y.	8,299,497	1.53	2404	132	23,000	35,097
Exxon	Houston, Tx.	7,952,177	15.53				
Shell	Houston, Tx.	7,790,808	7.92	24	141	19,509	26,000
Amoco	Chicago, Ill.	7,168,225	2.67	3665	98	17,113	19,509
Gulf	Pittsburgh, Pa.	7,028,701	7.86	2131	NA	17,187	27,676
Mobil	N.Y., N.Y.	6,752,328	5.01	NA	NA	NA	23,553
Standard of California	San Francisco, Ca.	4,982,476	6.47	952	8	7,911	17,764
Arco	Los Angeles, Ca.	4,563,353	-7.01	1788	113	NA	15,767
Phillips Petroleum	Bartlesville, Ok.	4,084,997	.09	2312	51	13,737	19,272
Sun	Philadelphia, Pa.	3,827,395	-.70	NA	NA	16,057**	16,057
Union	Palantine, Ill.	3,182,161	7.64	1366	65	13,296	14,500
Continental	Houston, Tx.	2,405,071	2.59	1099	NA	3,649	5,939
Cities Service	Tulsa, Ok.	1,736,622	-3.80	55	38	7,624	7,624
Standard of Ohio	Cleveland, Ohio	1,284,865	5.58	NA	NA	7,800	7,800
BP Oil	Montreal, Canada	847,864	-24.64	NA	NA	NA	NA
Getty	N.Y., N.Y.	679,925	4.12	109	9	2,202	2,441
Skelly	Tulsa, Ok.	621,444	4.48	1460	10	3,127	4,546
Boron (Sub. of	Standard of Ohio)	140,029	20.54	NA	NA	NA	NA
OTHER INTEGRATED MARKETERS							
Marathon	Findlay, Ohio	1,583,560	-0.10	384	38	2,127	3,564
Ashland	Ashland, Ky.	1,548,346	3.50	171	25	701	1,887
Clark	Milwaukee, Wis.	1,312,036	15.01	NA	11	1,854	1,854
Amerada Hess	N.Y., N.Y.	1,039,096	2.17	NA	NA	NA	NA
Tenneco Oil Co.	Houston, Tx.	819,869	-0.95	NA	NA	962	1,134
Murphy	El Dorado, Ark.	684,835	3.55	10	29	1,203	1,203
American Petrofina	Dallas, Tx.	646,259	2.18	386	13	4,394	5,493
Triangle	Houston, Tx.	598,851	-9.15	NA	NA	NA	NA
Diamond Shamrock	Amarillo, Tx.	549,166	3.83	2	10	1,520	1,520
Tosco		358,387	123.22				
Vickers	Wichita, Kansas	353,403	31.75	NA	NA	908	908
Charter	Houston, Tx.	345,908	8.65	NA	NA	529	529
Crown Central	Baltimore, Md.	341,872	-9.14	NA	NA	NA	NA
Champlin	Fort Worth, Tx.	321,964	5.83	299	7	1,210	1,267
Apco	Oklahoma City, Ok.	283,912	8.01	---	1	1,398	1,398
Derby	Wichita, Kan.	263,689	2.53	1	1	626	626
Kerr-McGee	Oklahoma City, Ok.	263,292	-8.32	146	3	1,575	1,641
Powerine	Santa Fe Springs, Ca.	251,150	8.66	NA	NA	NA	NA
Husky	Denver, Colo.	250,782	2.65	104	2	716	729
North Western	St. Paul Park, Minn.	246,934	11.21	NA	NA	NA	NA
Pasco	Denver, Colo.	213,964	1167.86	50	9	1,200	1,200

TABLE 2.1-4 (Cont.)

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1973 OIL COMPANY MARKETING STATISTICS

Company Name	Home Office	Gasoline Sales (add 000 gal.) 1973	Gasoline Sales (add 000 gal.) % Change	Bulk Plants	Terminals	Service Stations**	Total Branded Retail Outlets
LaGloria	Houston, Tx.	204,618	2.43	NA	NA	NA	NA
Mohawk	Los Angeles, Ca.	182,107	29.25	NA	NA	225	225
Time	Los Angeles, Ca.	152,127	-28.05	NA	10	300	300
Delta	Conway, Ark.	149,194	55.83	NA	NA	NA	NA
Petroleum Marketing	McLean, Va.	137,401	-16.65	NA	1	135	135
Pennzoil	Houston, Tx.	131,282	-5.46	33	5	588	878
Union Texas	Houston, Tx.	126,769	6.45	NA	3	271	271
Caribou	Afton, Wyo.	124,147	-11.59	1	NA	58	58
Total Leonard	Alma, Mich.	120,156	-13.18	90	5	402	710
SUPPLIERS							
Rock Island	Indianapolis, Ind.	237,541	2.18	NA	NA	NA	NA
Golden Eagle	Los Angeles, Ca.	220,124	8.62	NA	NA	NA	NA
Beacon	Hanford, Ca.	154,865	-5.20	15	3	226	241
Cheker	S. Chicago Heights, Ill.	144,867	18.42	NA	NA	247	247
M&A		139,532	-24.42	NA	NA	NA	NA
Fletcher O&R	Carson, Ca.	125,049	-22.57	NA	NA	NA	NA
Little America	Cheyenne, Wyo.	121,054	15.37	NA	NA	NA	NA
MARKETERS							
Koch Ref.	Wichita, Kan.	241,371	22.64	NA	NA	290	290
Martin Oil	Blue Island, Ill.	185,316	-9.23	6	5	217	227
Gasland		160,316	-12.76				
COOPERATIVES							
Cenex	St. Paul, Minn.	342,795	6.64	764	4	672	672
Farmland	Kansas City, Mo.	205,619	4.38	869	16	NA	1,192
Coop Assns.		170,206	13.16	NA	NA	NA	NA
MISCELLANEOUS							
		169,561	8.71				
TOTAL		104,154,631	3.85				

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*Companies with less than 0.12% of the market are not listed.

**Service stations are defined as retail outlets with more than 50% of their dollar value coming from the sale and service of petroleum products.

NA = Information Not Available.

[1] Category Definitions:

- I. Integrated Marketers - Produce, refine, transport, and market in interstate commerce. Market under their own brand in 24 or more states.
- II. Other Integrated Marketers - Transport and/or market in interstate commerce. Produce and refine, also, but one or the other of these functions may not be substantial in their over-all operation. Market with their own brand or brands in one to 23 states.
- III. Suppliers - Transport and/or market in interstate commerce. May market directly and/or indirectly. May produce and/or refine, but neither function is substantial in their over-all operation. Instead, their distributive functions are operational because of exchanges and/or special purchasing arrangements.
- IV. Marketers - Do not supply other marketers directly or indirectly. Do not utilize brands, bulk plants, or outlets of any company in groups I, II, and III, and are not subsidiaries or jobbers for any entity other than themselves. May deal in crude, but exert no control over, and are free from control by any company in groups I, II, and III.
- V. Cooperatives - Generally serve a nonretail public, although some engage in branded sales. May or may not be integrated.
- VI. Miscellaneous - Unbranded, nonmarketing operations (research companies, natural-gas producers, railroads, etc.) reporting net-taxable gallonages.

Source: NPN Mid-May Factbook, 1974 (NA-168).

integrated marketers, suppliers, marketers, cooperatives, and miscellaneous. These categories are defined in Table 2.1-4.

Current statistics included give the volume of gasoline sales in 1973 and the percentage change in sales from 1972 for each company. The number of distribution facilities is also indicated for each company listed. Bulk plant and terminal totals include both company-operated and jobber-operated facilities.

Marketing Terminals

Sizes and Number

Statistics from the 1967 Census of Business show that there were 2,701 terminals in that year. Total national liquid storage capacity of motor gasoline at terminals was 6.2 billion gallons with an average capacity of 2.3 million gallons per terminal (US-031). The same source indicated there were 26,338 bulk stations in 1967. Liquid storage capacity of motor gasoline at bulk stations was 1.0 billion gallons with an average capacity of 39,660 gallons (US-031).

Marketing Trends

Although 1972 Census of Business figures are not yet available,* state totals published to date indicate that gasoline was being distributed in 1972 through fewer bulk stations and terminals than in 1967 (see Table 2.1-1). Direct contact with oil companies and industry associations has confirmed this preliminary assessment and indicated that the reduction is primarily in the number of bulk stations. These contacts have indicated that there is a current trend toward phasing out bulk stations for economic reasons. More gasoline deliveries will be made directly from terminals with large tank trucks; less from the disappearing bulk stations with small trucks. Storage volumes will be added at terminals to compensate for bulk terminal reductions. The decrease in number of bulk stations will not necessarily have a major impact on overall marketing operations, however.

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* Complete 1972 Census of Business statistics are scheduled for publication in December, 1974.

Again, without the benefit of complete 1972 statistics, it is presumed that the combined sales volume at bulk stations and terminals has increased at a rate commensurate with the steady increase in gasoline consumption.

Gasoline Service Stations

Sizes and Number

In 1973 there were 218,000 service stations (NA-168). A gasoline service station is defined by the U.S. Department of Commerce as a retail outlet with more than 50% of its dollar volume coming from the sale and service of petroleum products. As described in the following section on marketing trends, the total number of gasoline service stations is undergoing rapid change. A survey conducted in May and June 1974, by Audits and Surveys, Inc., a New York firm reveals that in 1974 there are 196,000 U.S. service stations, a total which is down 9.1% from their 1973 survey figure of 216,000 (AU-020).

Detailed breakdowns of service station sizes as functions of sales volumes are difficult to obtain due to the reluctance of oil companies to make this information public. In 1973, average monthly service station throughput was 30,800 gallons per month according to an estimate by Lundberg Survey, Inc. (LU-044).

An EPA analysis of service station sales statistics from the 1967 Census of Business reveals the following totals for the number of stations in various size categories.

Service Station Sizes Gallons/Year Sold	Number Stations in 1967
Less than 150,000	54,100
150,000-200,000	17,000
200,000-250,000	21,200
250,000-300,000	25,500
Larger than 300,000	98,100
	216,000

Source: Maxey, Robert, EPA, personal communication, 10 September 1974 (MA-314).

Marketing Trends

Two trends are evident when looking at gasoline marketing operations at service stations during the last five years:

(1) retail sales have increased, and

(2) the total number of service stations has decreased.

These trends are charted in Figure 2.1-3.

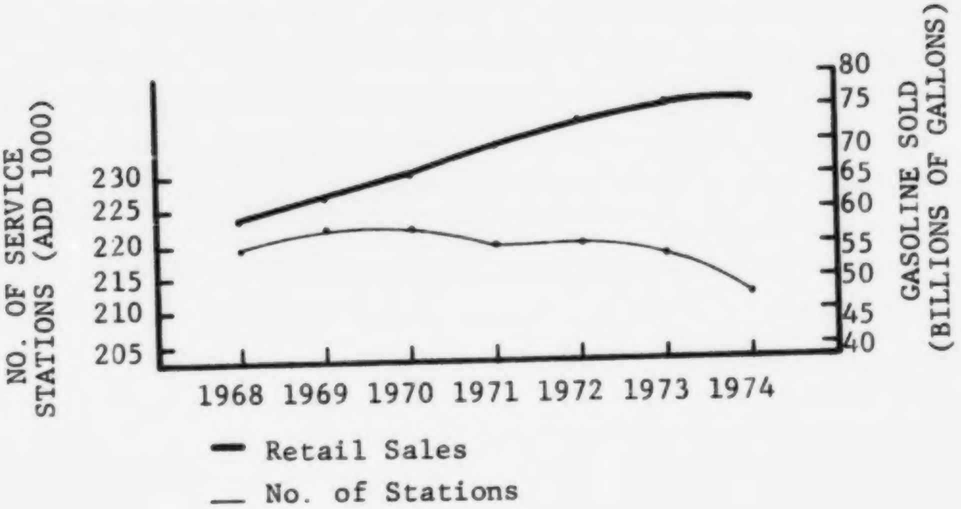

FIGURE 2.1-3 - MARKETING TRENDS AT GASOLINE SERVICE STATIONS

Source: NPN Mid-May Factbook, 1974 (NA-168)

National Petroleum News has documented the decline in service station construction. In 1973, the average oil company closed 750 stations and opened 97 (NA-168). The 1974 survey by Audits and Surveys, Inc., confirms the continuation of this trend in 1974 as previously mentioned. A review of selected major and independent oil company 1973 annual reports reinforces this picture. Operational policy for all companies reviewed included a program of closing those stations considered economically marginal. New construction programs are underway, however, to meet intensive growth demands.

Accompanying the decline in the number of service stations has been an increase in throughput per station to accommodate the increased volume of gasoline consumption nationally. As indicated in Table 2.1-5, passenger car gasoline sales have increased from 58.1 billion gallons in 1968 to an estimated 75.8 billion gallons per year in 1974. Service station dollar sales show an accompanying increase during this period.

Other Gasoline Retail Outlets

In 1973, it is estimated that there were between 125,000 and 150,000 retail outlets selling gasoline which did not fall under the Department of Commerce definition of service stations. In other words, the dollar return from petroleum product sales and service at these facilities did not equal 50% of their total sales volume. Included in this category of retail outlets are convenience stores with gasoline pumps, automotive stores, and department stores with an automotive department. Specific data on these "non-service station" retail outlets cannot be obtained from publicly available

TABLE 2.1-5

NUMBER OF GASOLINE SERVICE STATIONS AND SALES VOLUME

1968 - 1974

Year	Stations	Annual Gasoline Sales to Passenger Cars (Millions of Gallons)	Average Gasoline Sales to Passenger Cars/Station (Gallons/Month)	Total Sales (Billions of Dollars)	% Increase In Sales (Dollars)
1968	219,100	58,127	22,100	24.5	---
1969	222,000	62,047	23,300	25.9	5.7
1970	222,000	65,297	24,500	28.0	8.1
1971	220,000	68,821	26,100	29.2	4.3
1972	220,000	73,121	27,700	31.0	6.2
1973	218,000	75,842	29,000	34.4	11.3
1974[2]	212,000	75,842	29,800	37.5	9.0

Source: NPN Mid-May Factbook, 1974 (NA-168).

[1] Gasoline service stations are defined as retail outlets with 50% or more of dollar volume coming from sale and service of petroleum products.

[2] 1974 figures are NPN estimates.

statistical resources. It is estimated that convenience food stores average 2,000-3,000 gallons per month while some large department stores may average 100,000-150,000 gallons per month.

2.1.1.3 Gasoline Market - Projections

A 1972 survey of 30 energy forecast reports reveals that the majority of these forecasts assume a 3.5 percent annual growth rate in all transportation energy consumption for the years 1970-1980 (SU-049). The basic premise behind this assumption is that individual cars will remain the primary mode of transportation in the U.S., at least until 1980. Lead times for mass transit systems and for the development of alternative fuels will prevent such future options from having any major impact before 1980 (SH-121).

These same basic premises have been used in this report to project U.S. gasoline consumption to 1980. The methodology used to develop this projection is described below.

Projection and Methodology - Vehicles and Gasoline Consumed

Due to the many variables involved, it is difficult to project gasoline consumption accurately. The following assumptions have been made in this study for projecting automobile gasoline consumption to 1980 for each state.

(1) the U.S. population will continue to grow,

(2) passenger cars will be smaller and lighter; average miles per gallon will increase, and

(3) the average number of miles traveled per auto per year will remain constant.

Each of these assumptions is explained below.

(1) A 1974 projection of U.S. population indicates that there will be 223 million persons in the U.S. in 1980 (ST-185). This figure reflects a 1.04 percent annual increase from 1969 to 1990. National Petroleum News has projected that there will be 121 million automobiles in 1980 (NA-171). Thus, the projected ratio of persons to automobiles in 1980 is expected to be 1.85 as compared with a 1972 ratio of 2.14. Assuming that the ratios of persons per automobile will change in each state at the same rate, the projected number of automobiles has been calculated for each state (see Table 2.1-6).

(2) It has been assumed that a trend toward lighter, smaller automobiles, which is already apparent to some degree, and the use of catalytic converters will continue with a resultant increase in the number miles per gallon of gasoline.

(3) For the purpose of this study, it has also been assumed that the average number of miles traveled per automobile will not increase, but will remain at the 1973 level of 10,184 miles per year.

TABLE 2.1-6
GASOLINE MARKETING BY STATE

State	Population (in thousands) 1972^1	Population (in thousands) 1980^2	Automobiles (in thousands) 1972^3	Automobiles (in thousands) 1980	Automobile Gasoline Consumption (in million gallons) 1972	Automobile Gasoline Consumption (in million gallons) 1980	Service Stations 1972^4	Projected Change in Gasoline Consumption (in million gallons)
New England	12,100	13,000	5,760	7,140	4,350	4,760	11,105	410
Maine	1,030	973	451	494	341	329	1,224	-12
New Hampshire	771	843	368	466	279	310	888	31
Vermont	462	482	215	259	162	172	596	10
Massachusetts	5,790	6,270	2,550	3,200	1,930	2,130	4,698	200
Rhode Island	968	1,030	475	585	359	390	901	31
Connecticut	3,080	3,360	1,700	2,140	1,280	1,430	2,798	150
Mideast	43,000	45,900	17,500	21,700	13,200	14,500	32,270	1,300
New York	18,370	19,400	6,270	7,670	4,730	5,110	11,359	380
New Jersey	7,370	8,080	3,460	4,390	2,610	2,920	5,768	310
Pennsylvania	11,930	12,600	5,460	6,700	4,120	4,460	11,256	340
Delaware	565	627	270	346	204	230	557	26
Maryland	4,060	4,470	1,830	2,330	1,380	1,550	3,012	170
Dist. Columbia	748	750	239	277	180	184	318	4
Great Lakes	40,800	44,000	18,940	23,700	14,300	15,760	42,270	1,460
Michigan	9,080	9,740	4,270	5,320	3,220	3,540	8,919	320
Ohio	10,700	11,700	5,490	6,920	4,140	4,610	11,723	790
Indiana	5,240	5,780	2,310	2,950	1,740	1,960	6,235	220
Illinois	11,300	12,100	4,900	6,080	3,700	4,050	10,211	350
Wisconsin	4,520	4,740	1,970	2,380	1,490	1,590	5,182	100

(F) = Final 1972 Statistics

NA = Not Available

TABLE 2.1-[illegible] (Cont.)

State	Population (in thousands) 1972[1]	Population (in thousands) 1980[2]	Automobiles (in thousands) 1972[3]	Automobiles (in thousands) 1980	Automobile Gasoline Consumption (in million gallons) 1972	Automobile Gasoline Consumption (in million gallons) 1980	Service Stations 1972[4]	Projected Change in Gasoline Consumption (in million gallons)
Plains	16,590	17 100	7,850	9,190	5,930	6,120	23,304	190
Minnesota	3,860	4,120	1,870	2,160	1,410	1,440	4,585	30
Iowa	2,880	2,910	1,450	1,700	1,090	1,130	4,484	40
Missouri	4,750	5,070	2,030	2,510	1,530	1,670	6,280	180
N. Dakota	632	579	290	308	219	205	910	14
S. Dakota	679	655	312	348	236	232	1,171	4
Nebraska	1,530	1,500	778	882	587	587	2,265	0
Kansas	2,260	2,230	1,122	1,280	923	852	3,609	-71
Southeast	45,200	49,800	21,330	27,400	16,100	18,260	56,777	2,160
Virginia	4,760	5,300	2,170	2,800	1,640	1,860	4,648	220
W. Virginia	1,780	1,830	669	796	505	530	2,156	25
Kentucky	3,300	3,610	1,516	1,920	1,140	1,280	3,921	140
Tennessee	4,030	4,560	1,820	2,390	1,370	1,590	5,157	220
N. Carolina	5,210	5,740	2,530	3,220	1,910	2,140	6,946	230
S. Carolina	2,670	2,820	1,200	1,470	906	979	3,720	73
Georgia	4,720	5,150	2,370	3,000	1,790	2,000	6,730	210
Florida	7,260	8,930	4,130	5,880	3,120	3,920	9,199	800
Alabama	3,510	3,750	1,750	2,170	1,320	1,450	4,510	130
Mississippi	2,250	2,330	920	1,100	695	733	2,725	38
Louisiana	3,700	3,740	1,520	1,780	1,150	1,190	3,921	40
Arkansas	1,980	2,090	732	897	553	597	3,144	44
Rocky Mt.	5,300	5,460	2,740	3,270	2,070	2,180	7,829	110
Montana	719	670	375	406	283	270	1,190	13
Idaho	756	708	382	414	288	276	1,193	-12
Wyoming	345	331	174	194	131	129	772	-2

TABLE 2.1-6 (Cont.)

State	Population (in thousands) 1972[1]	Population (in thousands) 1980[2]	Automobiles (in thousands) 1972[3]	Automobiles (in thousands) 1980	Automobile Gasoline Consumption (in million gallons) 1972	Automobile Gasoline Consumption (in million gallons) 1980	Service Stations 1972[4]	Projected Change in Gasoline Consumption (in million gallons)
Colorado	2,360	2,590	1,270	1,620	959	1,080	3,170	121
Utah	1,130	1,160	538	640	406	426	1,504	20
Southwest	17,300	18,200	8,350	10,300	6,300	6,830	25,459	530
Oklahoma	2,630	2,760	1,330	1,610	1,000	1,070	4,153	70
Texas	11,600	12,200	5,550	6,780	4,190	4,520	17,118	330
New Mexico	1,070	1,060	500	573	378	382	1,831	4
Arizona	1,950	2,230	972	1,290	734	859	2,357	125
Far West	27,800	28,900	14,300	18,030	10,800	12,000	27,445	1,200
Washington	3,440	3,550	1,700	2,030	1,280	1,350	3,945	70
Oregon	2,180	2,340	1,230	1,530	929	1,020	2,828	91
Nevada	527	616	298	405	225	270	798	45
California	20,500	22,500	10,600	13,500	8,000	9,000	19,153	1,000
Alaska	325	333	101	120	76	80	241	4
Hawaii	809	848	392	476	296	317	480	21
Total	208	224	96,900	121,000	73,200	80,600	226,459	7,400

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[1] Statistical Abstract of the U.S., 1973, 94th. ed. Table No. 13.

[2] "State Projections of Income, Employment, and Population to 1990", Survey of Current Business 54(4), 32 (1974) (ST-185).

[3] NPN Mid-May Factbook, 1974 (NA-168).

[4] 1972 Census of Business, Retail Trade, Preliminary Area Statistics.

2.1.1.3 Gasoline Market - Projections (Cont.)

Based on assumptions (2) and (3) given above, the average number of gallons consumed per automobile has been projected for the years 1974-1980:

Year	Miles/Year	Miles/Gallon	Average Gallons of Gasoline Consumed Per Year
1974	10,184	13.7	743
1975	10,184	14.0	727
1976	10,184	14.2	717
1977	10,184	14.4	707
1978	10,184	14.7	793
1979	10,184	15.0	679
1980	10,184	15.3	666

Source: NA-168

Based on these averages, the estimated number of gallons of gasoline to be consumed by automobiles has been calculated and is given nationally and by state in Table 2.1-6. The estimated change in consumption between 1972 and 1980 is also indicated.

The total number of motor vehicles (automobiles plus trucks, buses, etc.) is projected to grow at an annual rate of 3 percent between 1973 and 1980 (NA-171). Based on this growth rate, there will be 148 million vehicles in 1980; 121 million automobiles and 27 million other types of vehicles.

Assuming that the average annual gasoline consumption by these other types of vehicles will remain at the 1972 level of 1,303 gallons per year, these vehicles will consume some 35.2 billion gallons of gasoline in 1980 bringing total gasoline consumption to 115.8 billion gallons in 1980.

In summary, the projected total gasoline consumption for all vehicles represents an average annual increase of 1.75 percent from 1973 to 1980. Thus, gasoline consumption will continue to increase nationally through 1980 but at a slower rate than in past years assuming increased passenger car gasoline mileage and no change in the average number of miles traveled per year.

Impact of Projected Gasoline Consumption

(1) By Region

Increased gasoline consumption necessarily impacts all aspects of the gasoline marketing industry. Distribution facilities must expand to meet increased throughput. Using the increase in gasoline consumption between 1974 and 1980, as shown in Table 2.1-6, it is possible to predict on a regional and state level the areas where growth in gasoline distribution facilities will most likely occur. Regions are ranked below on the basis of their projected increase in automobile gasoline consumption.

2.1.1.3 Gasoline Market - Projections (Cont.)

Rank	Region	1972-1980 Change in Automobile Gasoline Consumption (millions of gallons)
1	Southeast	2,160
2	Great Lakes	1,460
3	Mideast	1,300
4	Far West	1,200
5	Southwest	530
6	New England	410
7	Plains	190
8	Rocky Mountain	No Growth

(2) Marketing Terminals

Wholesale marketing facilities, terminals and bulk stations, will require expansion to meet the increased throughput required by gasoline consumption demands. As previously mentioned, it is expected that bulk stations will be phased out for economic reasons and the trend will be toward distribution through larger terminal facilities.

(3) Service Stations and Other Retail Outlets

It is expected that the total number of gasoline service stations will continue to decrease over the next two to three years as economically marginal stations are closed. The remaining stations are projected to be financially stronger and more profitable to oil companies once the marginal stations are gone (EM-008). Expansion of existing stations to meet increased consumption demands is to be expected. The addition of more convenience store pumps is also expected. In addition, new gasoline service stations will continue to be built by oil companies to meet consumption demands in rapidly growing population areas.

2.1.2 Air Pollution Contribution

The gasoline marketing industry contributes hydrocarbon compounds to the atomosphere through the mechanism of evaporation during the many handling processes involved in transferring gasoline from the refinery to the automobile. In studying these evaporation losses it is important to assess the nature and magnitude of the problems associated with hydrocarbon emissions. Although the hydrocarbons from gasoline marketing do not contribute directly to smog and its adverse effects, several of the hydrocarbons do undergo reactions to form products which do produce undesirable smog. This section reviews the direct and indirect adverse effects of such hydrocarbon emissions, the quantity of atmospheric hydrocarbons contributed by the gasoline marketing industry, and the seasonal characteristics of these contributions.

2.1.2.1 Adverse Effects of Hydrocarbon Emissions

Very few hydrocarbons in the atmosphere directly effect the environment. However, many hydrocarbons termed "reactive" participate to various degrees in photochemical reactions to form photochemical oxidants which do have adverse effects on plants, animals, and materials. The hydrocarbons contained in gasoline vapor are reported to be composed of 42% to 65% reactive hydrocarbons (MS-001, TR-042). Appendix B of this report presents the chemical composition of gasoline and its vapors, lists the reactivities of several hydrocarbon classes, and describes the photochemical reaction. Presented here are some of the direct and indirect effects produced by hydrocarbons such as those found in gasoline vapor.

Effects on Human Health

Effects on human health are of paramount importance in any consideration of air pollutants. However, the wide variety of compounds in photochemical smog effectively prevent singling out specific compounds as contributors to specific adverse effects. There is little evidence that hydrocarbons as emitted to the air have direct adverse effects on the health of the general public. The documented health effects are limited to eye, respiratory irritation, and aggravation of chronic respiratory ailments due to exposure to photochemical oxidants which are the result of subjecting hydrocarbons to the photochemical reaction.

The major contributors to eye and respiratory irritation are aldehydes, organic peroxides, peroxynitrates, and ozone. Peroxyacetylnitrate (PAN) was found to induce increased oxygen uptake under stressful exercise. Studies in Los Angeles have found that prolonged exposure of guinea pigs to ambient Los Angeles air increased pulmonary airflow rates. There is also wide spread concern over the potentially carcinogenic effects of long term human exposure to the airborne polycyclic aromatic hydrocarbons.

In summer, although hydrocarbons do not directly effect human health, their derivaties from the photochemical reaction, in atmospheric concentrations, cause eye and respiratory irritation, and aggravation of chronic respiratory ailments (TR-042).

Effects on Vegetation

Of the primary hydrocarbon air pollutants, ethylene is the only one producing significant damage at atmospheric concentrations. Oxidants resulting from the photochemical reaction produce the greatest amount of vegetation damage. This damage is primarily in the form of growth supression. It is difficult to assess vegetation damage due to air pollution but estimates of pollution vegetation damage in California were $100 million annually and for the nation $500 million annually (TR-042). Table 2.1-7 (TR-042) below details the contribution of each pollutant to the California vegetation damage.

TABLE 2.1-7
CONTRIBUTION OF POLLUTANTS TO VEGETATION DAMAGE IN CALIFORNIA

Pollutants	Percentage of Damage
Ozone	50%
Peroxyacetylnitrate	18%
Fl	15%
Ethylene	14%
SO_2	2%
Particulates	1%

Materials Damage

Materials damage by atmospheric hydrocarbons and their oxidant derivaties is not well documented. Photochemical oxidants cause cracking and loss of elasticity in rubber and plastics, the formation of resistive coatings on electrical contacts, and discoloration and deterioration of architectural coatings. The San Francisco Bay Area estimated their materials damage due to hydrocarbons and photochemical oxidants to be $15 million annually (TR-042).

Other Effects

In addition to effects on health, vegetation, and materials, hydrocarbon and photochemical oxidant pollutants can be visually offensive and contribute to offensive odors. Offensive odors are a nuisance and can result in property depreciation and degradation of the general quality of life.

2.1.2.2 How Gasoline Marketing Contributes to Atmospheric Hydrocarbons

Gasoline is a mixture of many volatile hydrocarbon compounds which evaporate upon contacting air. The gasoline marketing industry significantly contributes to atmospheric hydrocarbon levels as a result of the numerous points of exposure of gasoline with air throughout the handling steps in gasoline marketing. Hydrocarbon vapor in vessels containing gasoline is displaced through vents to the atmosphere during refilling operations. These vapors also expand during temperature increases, venting hydrocarbons to the atmosphere. In addition, hydrocarbons are emitted from leaks and spills that occur throughout the marketing transfers such as during vehicle refueling.

2.1.2.3 Magnitude of Gasoline Marketing Emissions

The gasoline marketing industry contributes significantly to ambient hydrocarbon levels, and if left uncontrolled will become one of the three major sources of hydrocarbon emissions. Table 2.1-8 (FE-063) presents the national hydrocarbon emissions determined in EPA's 1968 Emissions Inventory. This data indicates that gasoline marketing emissions comprised 3.8% of the total hydrocarbon emissions.

If left uncontrolled, the gasoline marketing industry would become a greater contributor to future reactive hydrocarbon emission inventories. This is because other emission sources are being brought under control, because gasoline sales are increasing, and because of the increased reactivity of non-leaded gasoline vapors. Table 2.1-9 (TR-042) and Table 2.1-10 (TR-042) estimate future hydrocarbon and reactive hydrocarbon emissions for two Texas air quality control regions assuming no gasoline marketing controls. The Houston-Galveston region is typical of a highly industrialized metropolitan area and the Austin-Waco region is typical of a suburban-rural area. Future national emissions are expected to fall between the emissions of these two regions.

Table 2.1-11 summarizes data from Tables 2.1-9 and 2.1-10. It indicates that gasoline marketing, if left uncontrolled will contribute 12%-21% of the ambient reactive hydrocarbons in 1982, depending on the region. This relative increase in ambient hydrocarbon contribution is attributed to a steady increase in gasoline sales and a decline in emissions from other sources as they meet compliance schedules.

One factor not accounted for in Tables 2.1-9, 2.1-10, and 2.1-11 is the increased reactivity of gasoline vapors resulting from the switch to unleaded fuels. The higher aromatic

TABLE 2.1-8
NATIONAL EMISSIONS OF HYDROCARBON COMPOUNDS, 1968

Source	Organic Compound Emissions 10^6 Tons/Yr	Organic Compound Emissions Percent
Transportation		
Motor Vehicles	15.6	48.7
Aircraft	0.3	1.0
Railroads	0.3	1.0
Vessels	0.1	0.2
Nonhighway Use	0.3	1.0
Fuel Combustion	0.7	2.2
Industrial Processes	4.6	14.4
Solid Waste Disposal	1.6	5.0
Organic Solvents	3.1	9.7
Gasoline Marketing	1.2	3.8
Miscellaneous	4.2	13.0
Total	32.0	100.0

TABLE 2.1-9

HYDROCARBON EMISSIONS INVENTORY SUMMARY -- AIR QUALITY CONTROL REGION 7
HOUSTON - GALVESTON

SOURCE CATEGORY	TOTAL/REACTIVE EMISSIONS - Tons/Year											
	1970		1972		1975		1977		1980		1982	
	TOTAL	REACTIVE	TOTAL	REACTIVE	TOTAL	REACTIVE	TOTAL	REACTIVE	TOTAL	REACTIVE	TOTAL	REACTIV
I. FUEL COMBUSTION	36,678	0	38,145	0	40,346	0	42,180	0	44,747	0	46,581	0
II. PROCESS LOSSES												
A. AREA SOURCES	28,232	5,646	29,361	5,872	31,055	6,211	32,467	6,493	34,443	6,889	35,855	7,171
B. POINT SOURCES												
1. CHEMICAL PROCESSING	373,068	223,841	429,028	257,417	55,964	33,578	62,306	37,384	73,871	44,323	82,452	49,471
2. FOOD AND AGRICULTURAL	142	85	153	92	90	54	91	55	93	56	94	56
3. METALLURGICAL	831	0	956	0	350	0	358	0	372	0	380	0
4. MINERAL PRODUCTS	383	0	433	0	200	0	206	0	215	0	222	0
5. PETROLEUM REFINING	140,794	16,895	142,202	17,064	13,005	1,561	13,850	1,662	15,258	1,831	16,384	1,966
6. WOOD PROCESSING	1,008	605	1,260	756	588	353	602	361	627	376	641	385
7. SHIP AND BARGE LOADING	27,778	11,111	28,511	11,444	30,000	12,000	31,945	12,778	35,278	14,111	36,945	14,778
8. ALL OTHERS	2,474	1,484	2,796	1,678	960	576	997	598	1,057	634	1,099	659
C. TOTALS	574,710	259,667	634,800	294,323	132,212	54,333	142,822	59,331	161,214	68,220	174,072	74,486
III. SOLID WASTE DISPOSAL	9,251	0	9,621	0	10,176	0	10,639	0	11,286	0	11,749	0
IV. TRANSPORTATION												
A. MOTOR VEHICLES												
1. GASOLINE			113,107	83,620	90,419	67,977	69,826	52,976	50,646	38,768	44,361	34,260
2. DIESEL			1,933	870	2,178	980	2,386	1,074	2,739	1,232	3,021	1,360
3. OFF-HIGHWAY FUEL USAGE			6,938	3,122	7,018	3,158	7,188	3,234	7,254	3,264	7,536	3,391
C. AIRCRAFT			15,502	5,813	14,643	5,491	13,981	5,243	12,989	4,871	12,327	4,623
D. RAILROADS			623	280	623	280	623	280	623	280	623	280
E. VESSELS			3,855	3,084	4,098	3,271	4,253	3,403	4,498	3,598	4,694	3,755
F. GASOLINE EVAPORATION			16,331	10,615	18,948	12,316	20,803	13,522	24,008	15,605	26,471	17,206
G. TOTALS			158,289	107,404	137,918	93,473	119,060	79,732	102,757	67,618	99,033	64,875
V. MISCELLANEOUS	152	0	152	0	152	0	152	0	152	0	152	0
VI. GRAND TOTALS			841,007	401,727	320,804	147,806	314,853	139,063	320,156	135,838	331,587	139,361
VII. PER CENT REDUCTION					61.9	63.2	62.6	65.4	61.9	66.2	60.6	65.3

TABLE 2.1-10

HYDROCARBON EMISSIONS INVENTORY SUMMARY -- AIR QUALITY CONTROL REGION 3
AUSTIN - WACO

SOURCE CATEGORY	TOTAL/REACTIVE EMISSIONS - Tons/Year											
	1970		1971		1975		1977		1980		1982	
	TOTAL	REACTIVE	TOTAL	REACTIVE	TOTAL	REACTIVE	TOTAL	REACTIVE	TOTAL	REACTIVE	TOTAL	REACTIVE
I. FUEL COMBUSTION	1,586	0	1,600	0	1,695	0	1,758	0	1,853	0	1,916	0
II. PROCESS LOSSES												
A. AREA SOURCES	3,929	786	3,984	797	4,200	840	4,356	871	4,591	918	4,748	950
B. POINT SOURCES												
1. CHEMICAL PROCESSING	4,255	2,553	4,468	2,681	4,783	2,870	4,821	2,893	4,889	2,933	4,936	2,962
2. FOOD AND AGRICULTURAL	303	[illegible]	318	191	335	201	338	203	341	205	344	206
3. METALLURGICAL	224	0	224	0	224	0	224	0	224	0	224	0
4. MINERAL PRODUCTS	2,070	0	2,070	0	2,045	0	2,072	0	2,114	0	2,147	0
5. PETROLEUM REFINING	1	0	1	0	1	0	1	0	1	0	1	0
6. WOOD PROCESSING	893	536	991	595	914	548	928	557	950	570	967	580
7. ALL OTHERS	78	47	76	47	78	47	79	47	81	49	82	49
C. TOTALS	11,753	4,104	12,134	4,311	12,580	4,506	12,819	4,571	13,191	4,675	13,449	4,747
III. SOLID WASTE DISPOSAL	6,460	0	6,551	0	6,906	0	7,163	0	7,548	0	7,805	0
IV. TRANSPORTATION												
A. MOTOR VEHICLES												
1. GASOLINE			65,773	47,992	45,972	34,176	35,757	26,375	24,197	18,409	19,651	15,054
2. DIESEL			980	441	1,134	510	1,219	548	1,360	612	1,414	636
B. OFF-HIGHWAY FUEL USAGE			6,112	2,750	5,434	2,445	5,293	2,381	4,756	2,140	4,815	2,167
C. AIRCRAFT			14,244	5,342	13,883	5,205	13,725	5,147	13,489	5,058	13,331	4,999
D. RAILROADS			810	365	810	365	810	365	810	365	810	365
E. VESSELS			1,212	970	1,286	1,029	1,325	1,060	1,363	1,090	1,380	1,104
F. GASOLINE EVAPORATION			6,777	4,405	8,340	5,421	9,274	6,028	10,885	7,075	12,123	7,880
G. TOTALS			95,908	52,265	76,859	49,152	67,403	41,904	56,860	34,749	53,524	32,205
V. MISCELLANEOUS	43	0	43	0	43	0	43	0	43	0	43	0
VI. GRAND TOTALS			116,236	66,576	98,083	53,658	89,165	46,475	79,495	39,424	76,737	36,952
VII. PER CENT REDUCTION					15.6	19.4	23.3	30.2	31.6	40.8	34.0	44.5

TABLE 2.1-11
SUMMARY OF HYDROCARBON EMISSION TRENDS FROM GASOLINE MARKETING

	1971		1975		1977		1980		1982	
	Total	Reactive	Total	Reactive	Total	Reactive	Total	Reactive	Total	Reactive
Austin-Waco Region										
Total hydrocarbon emissions T/Y	116,236	66,576	98,083	53,658	89,186	46,475	79,495	39,424	76,737	36,952
Gasoline marketing emissions tons/year	6,777	4,405	8,340	5,421	9,274	6,028	10,885	7,075	12,123	7,880
% increase over 1971	0	0	23	23	37	37	61	61	79	79
% of total hydrocarbon emissions	5.8	6.6	8.5	10.1	10.4	13.0	13.7	17.9	16.0	21.3
Houston-Galveston Region										
Total hydrocarbon emissions T/Y	841,007	401,727	320,804	147,806	314,853	139,063	320,156	135,838	331,587	139,361
Gasoline marketing emissions										
tons/year	16,331	10,615	18,948	12,316	20,803	13,522	24,008	15,605	26,471	17,206
% increase over 1971	0	0	16	16	27	27	47	47	62	62
% of total hydrocarbon emissions	1.9	2.6	5.9	8.3	6.6	9.7	7.5	11.5	8.0	12.3

content of unleaded fuels is expected to raise the reactivity of gasoline vapors 12% for premium and 28% for regular grades (MS-001).

2.1.2.4 Seasonal Characteristics - Photochemical Oxidant Levels

The ambient level of photochemical oxidants is lowest in the winter season. This coincides with the season when the efficiency of the vapor balance recovery system is the lowest. Photochemical reaction rates are lowest during the winter months when solar radiation is at a minimum and the ambient temperatures are low. Figures 2.1-4 through 2.1-11 present the one-hour photochemical oxidant maximas and the frequency that ambient standards were surpassed at several sampling locations (EN-182).

At all sampling locations, the ambient photochemical oxidant standard was not surpassed in the months of January and December, and for most of the sampling locations the standard was not surpassed in the months of January, February, November, and December. During these months, the average temperatures were in the low 50's or lower.

Photochemical oxidant production is greatest in the warm summer season when ultraviolet radiation is at its peak. Figures 2.1-4 through 2.1-11 reflect this trend, indicating June, July, and August to be the months when this problem is most acute.

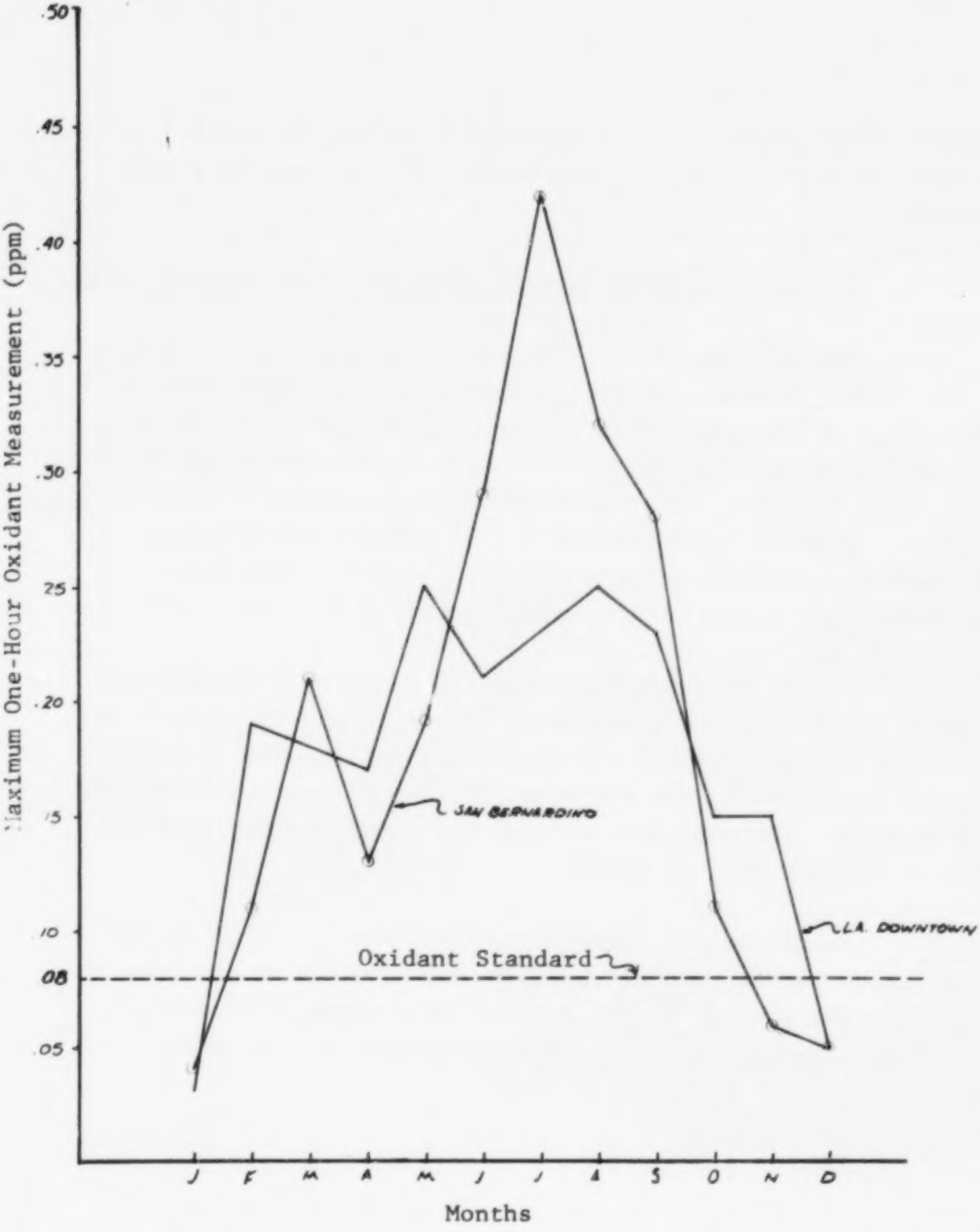


FIGURE 2.1-4 - MONTHLY OXIDANT MAXIMA, LOSS ANGELES AND SAN BERNADINO, CALIFORNIA - 1972

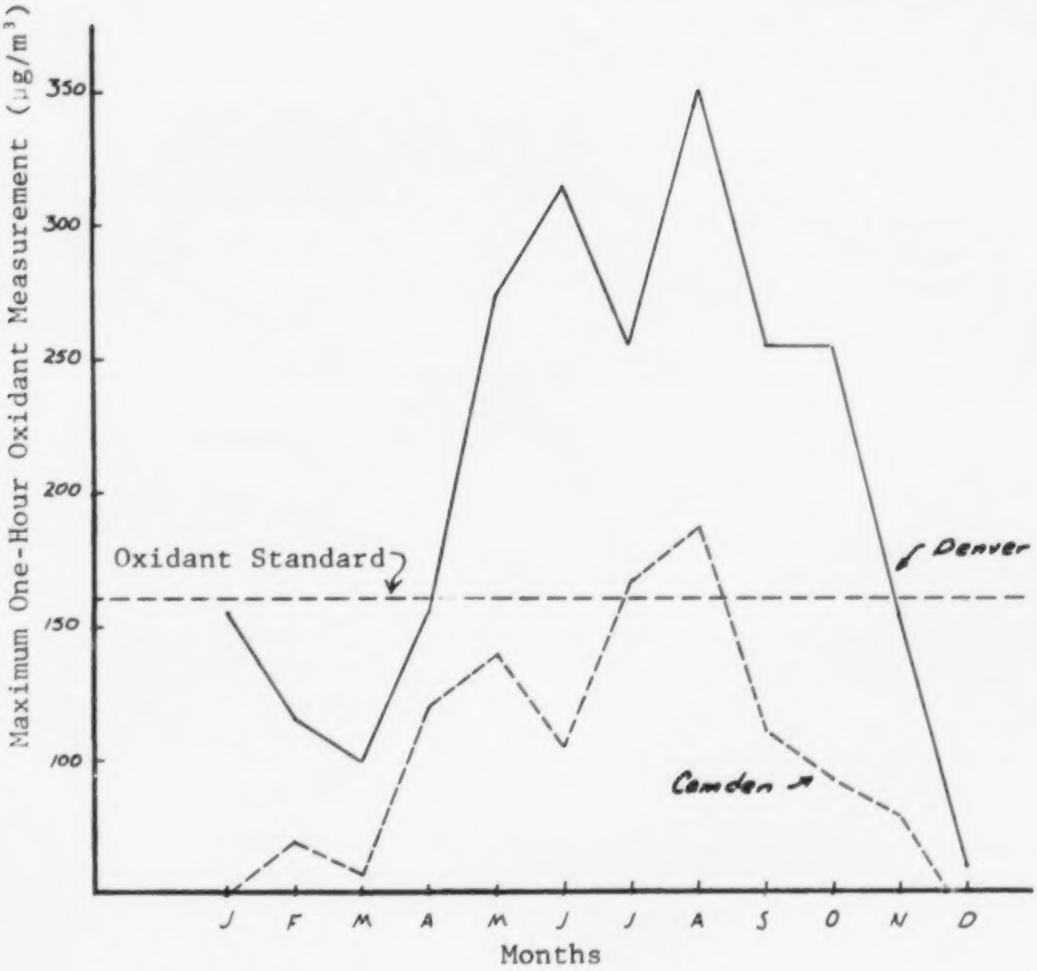


FIGURE 2.1-5 - MONTHLY OXIDANT MAXIMA, CAMDEN, NEW JERSEY AND DENVER, COLORADO - 1972

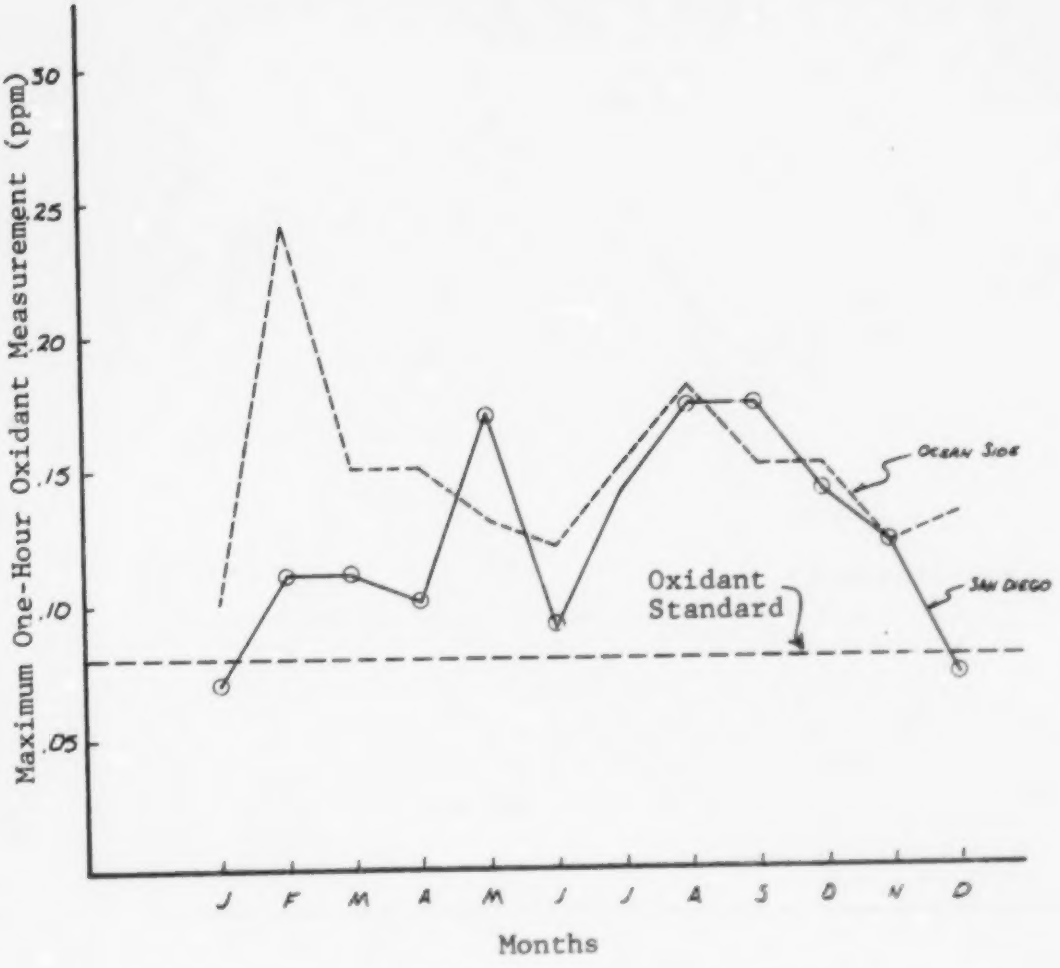


FIGURE 2.1-6 - MONTHLY OXIDANT MAXIMA, SAN DIEGO AND OCEANSIDE, CALIFORNIA - 1972

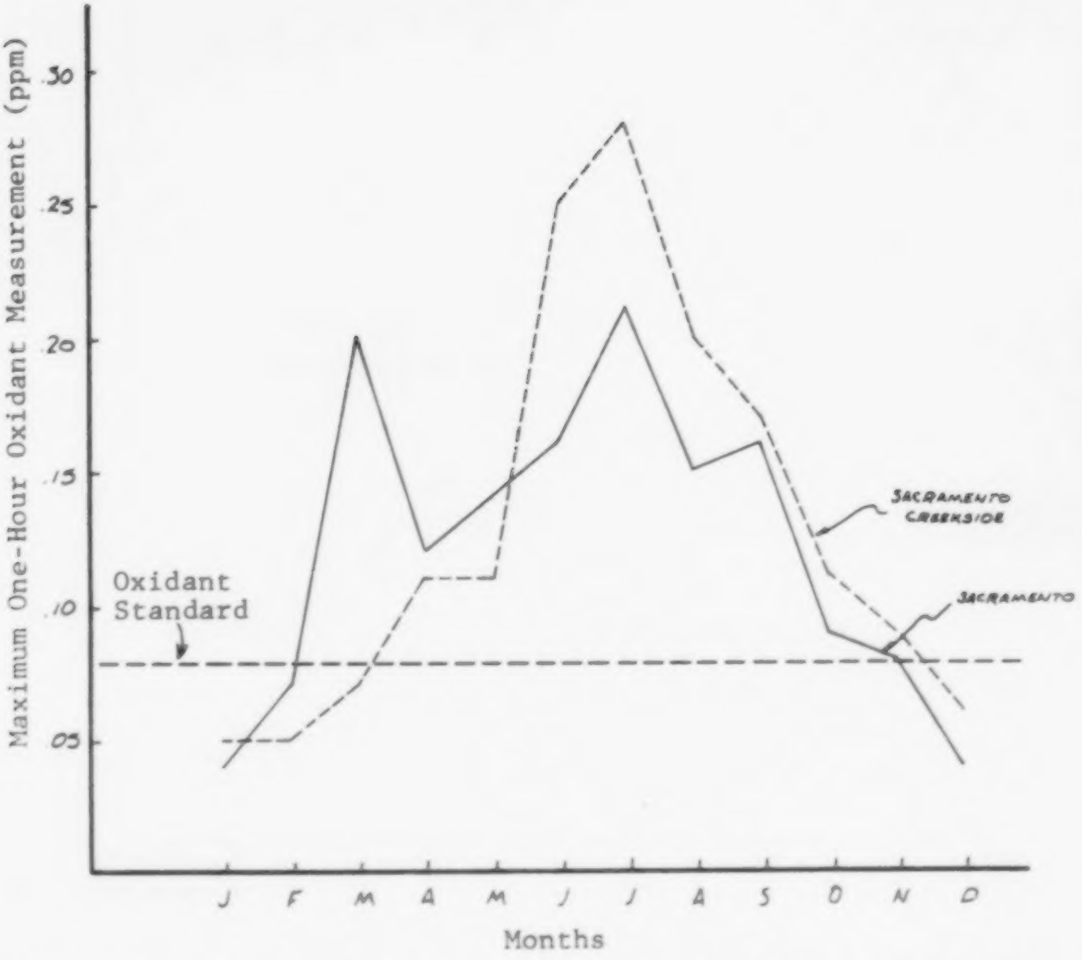


FIGURE 2.1-7 - MONTHLY OXIDANT MAXIMA, SACRAMENTO CALIFORNIA - 1972

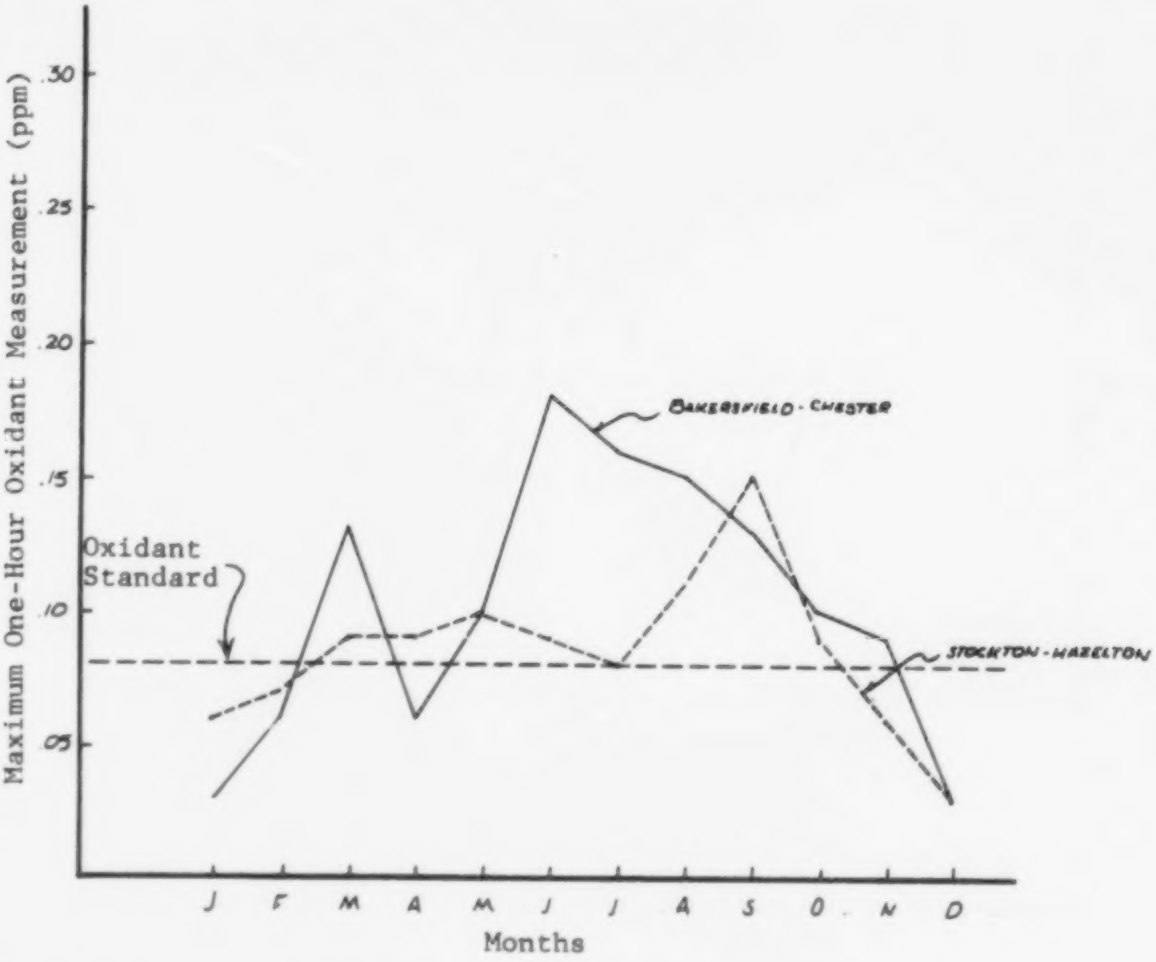


FIGURE 2.1-8 - MONTHLY OXIDANT MAXIMA, BAKERSFIELD AND STOCKTON, CALIFORNIA - 1972

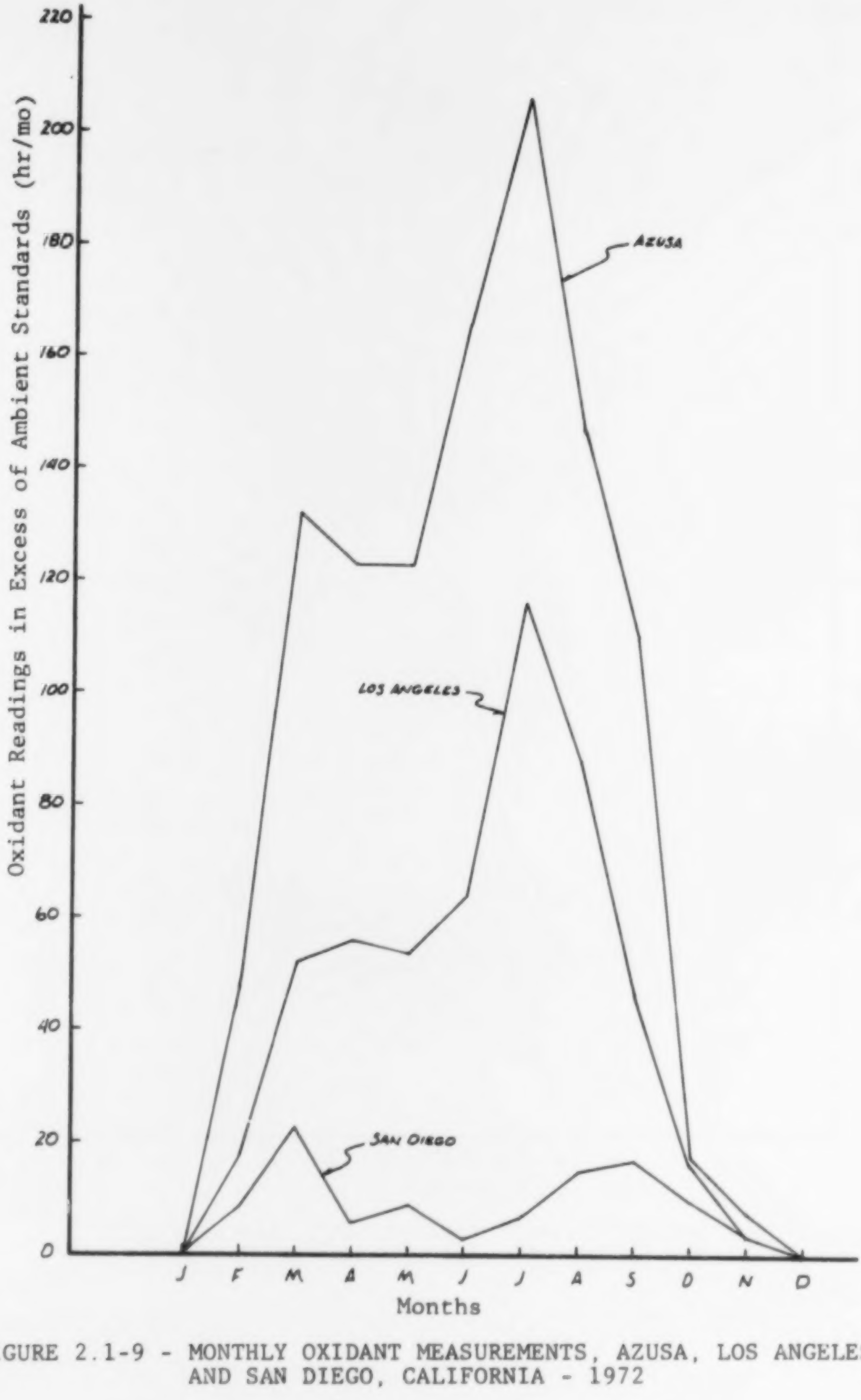


FIGURE 2.1-9 - MONTHLY OXIDANT MEASUREMENTS, AZUSA, LOS ANGELES, AND SAN DIEGO, CALIFORNIA - 1972

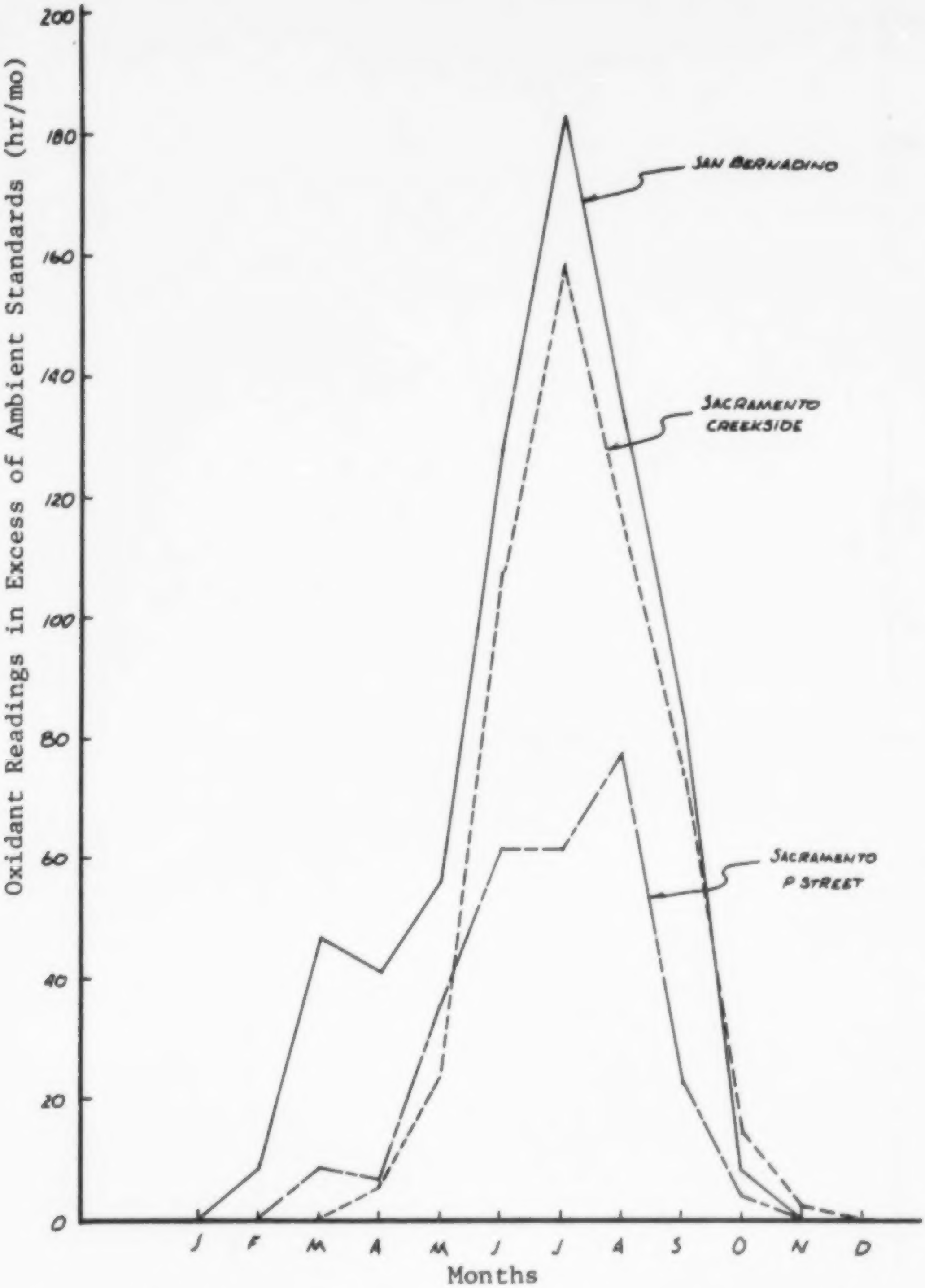


FIGURE 2.1-10 - MONTHLY OXIDANT MEASUREMENTS, SAN BERNADINO AND SACRAMENTO, CALIFORNIA - 1972

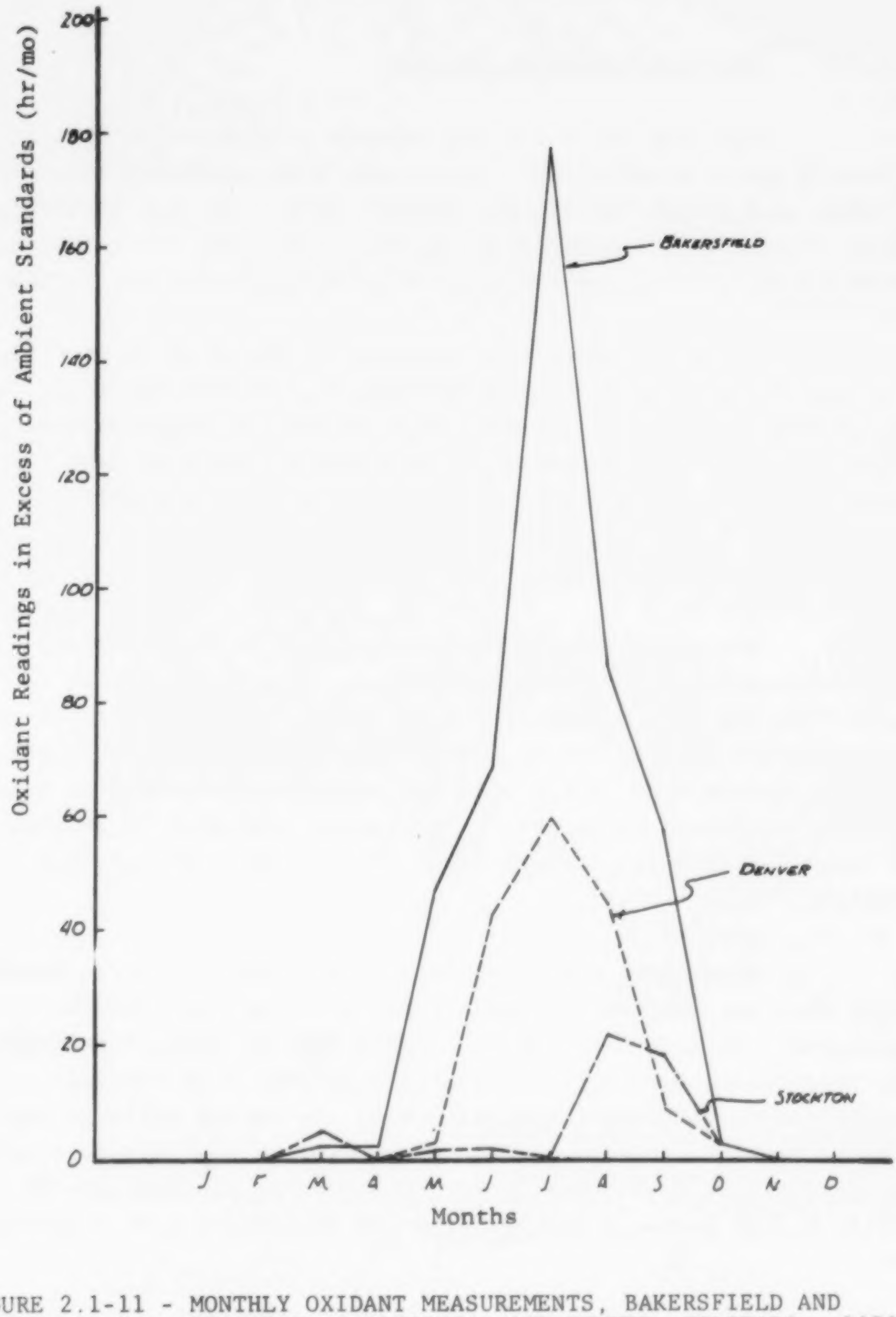


FIGURE 2.1-11 - MONTHLY OXIDANT MEASUREMENTS, BAKERSFIELD AND STOCKTON, CALIFORNIA, AND DENVER, COLORADO - 1972

2.1.3 Gasoline Marketing Systems

The gasoline marketing network is composed of two types of major intermediate facilities; bulk terminals and bulk plants, and retail facilities commonly called service stations. This section will briefly describe the main types of equipment associated with each of these gasoline distribution facilities.

The major sources of hydrocarbon emission in each type of facility will be mentioned only briefly in this section. Later sections of this document will present detailed discussions relating to the amount of emissions produced by each source and the technology available for emission control.

2.1.3.1 Bulk Terminals

The primary distribution facility in the gasoline marketing network is the bulk terminal. Gasoline products arrive at the bulk terminal by pipeline and are stored in large above-ground storage tanks. From these storage tanks the gasoline is loaded into tank trucks and transported to smaller bulk loading stations and to service stations. One million gallons of gasoline may pass through one of the larger bulk terminals daily.

Generally, the gasoline storage tanks are large enough that they are subject to regulations requiring that they be equipped with floating roofs. Hydrocarbon emissions from tanks of this design are limited to vapors escaping past the wall seals and to gasoline evaporating from the wetted walls as the liquid level is lowered. These minor hydrocarbon emissions are generally less than 0.3 gallons/1,000 gallons handled (DU-001). Table 2.1-12 contains a compilation of the nation's bulk storage

TABLE 2.1-12

U.S. BULK STORAGE CAPACITY BY TANK SIZE

(US-031)

Tank Size	Storage Capacity (10^3 gal)
Less than 42,000 gallons	95,975
42,000 - 62,000 gallons	242,837
63,000 - 83,000 gallons	249,542
84,000 - 104,000 gallons	137,078
105,000 - 209,000 gallons	214,148
210,000 - 1,049,000 gallons	186,960
1,050,000 - 2,099,000 gallons	221,792
2,100,000 - 6,299,000 gallons	1,386,821
6,300,000 - 20,999,000 gallons	2,357,165
Greater than 21,000,000 gallons	2,120,770

capacities as a function of tank size (US-031). Figures 2.1-12 and 2.1-13 are diagrams of fixed and floating roof tanks.

Hydrocarbon emissions from the tank truck loading racks are potentially much greater than those from the storage tanks at bulk terminals. As the empty tank trucks are filled, the hydrocarbons in the vapor space are displaced to the atmosphere, unless vapor collection facilities have been provided. The quantity of hydrocarbons contained in the displaced vapors is dependent on the Reid Vapor Pressure, temperature, method of tank filling, and the conditions under which the truck was previously loaded. Figure 2.2-14 is a schematic drawing of liquid and vapor flow through a typical bulk terminal.

2.1.3.2 Marine Terminals

There are no known marine terminals equipped with secondary recovery units. It is anticipated, however, that new source facilities ultimately will be subject to control and that equipment similar to that used in bulk terminals will be applicable to recovering hydrocarbon vapors from marine terminals. Due to limited data, no further information is provided on marine terminal vapor recovery systems.

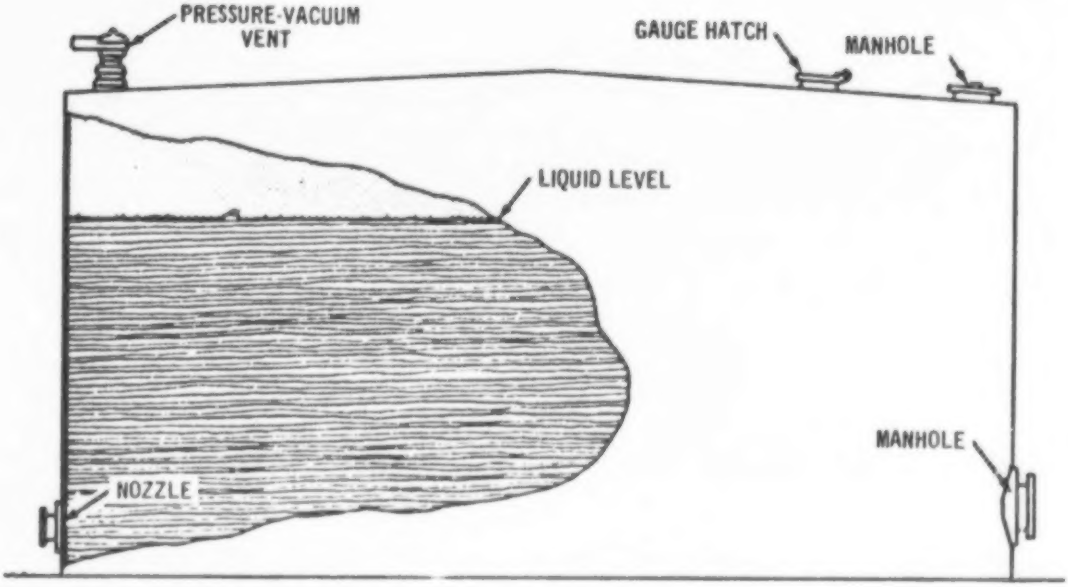

PRESSURE-VACUUM VENT
GAUGE HATCH
MANHOLE
LIQUID LEVEL
MANHOLE
NOZZLE

FIGURE 2.1-12 - DIAGRAM OF A FIXED ROOF TANK (EN-071)

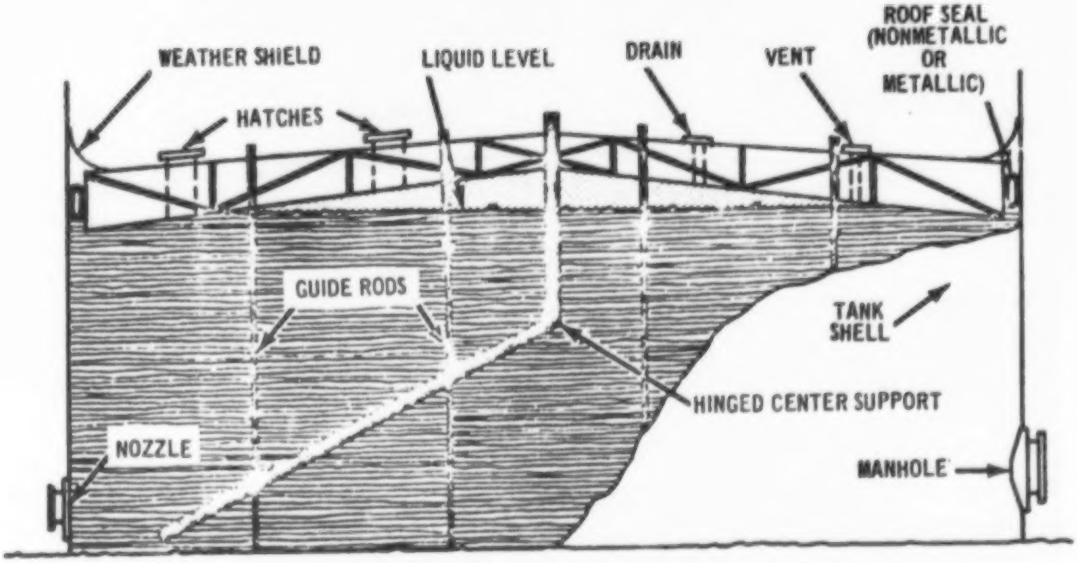
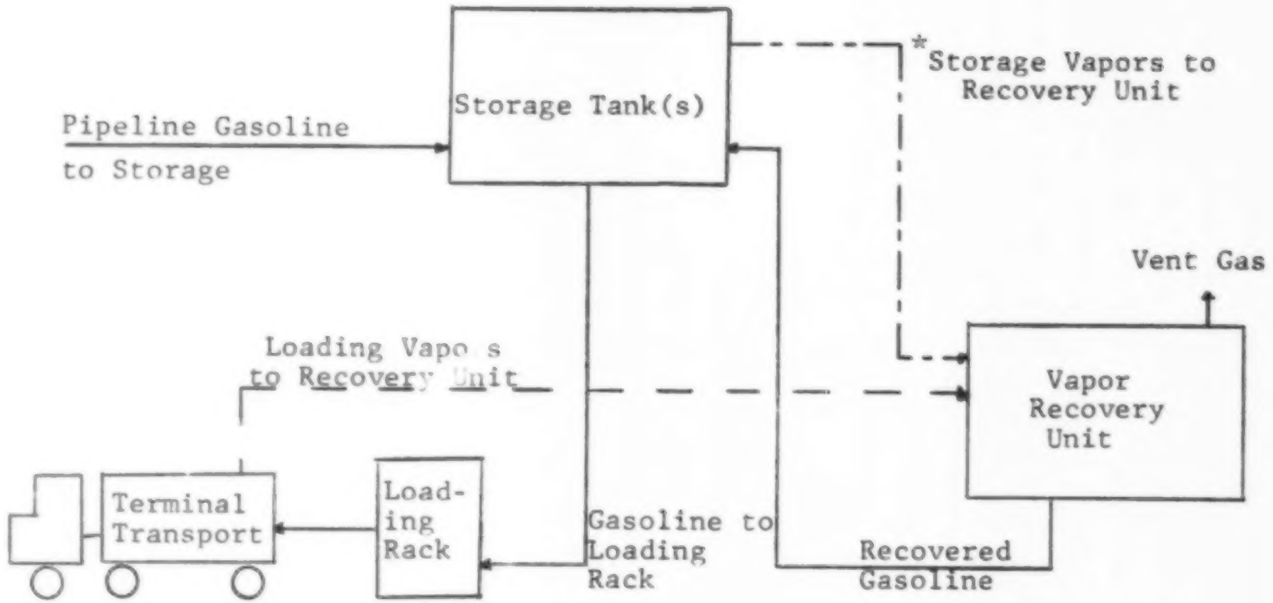

WEATHER SHIELD
HATCHES
LIQUID LEVEL
DRAIN
VENT
ROOF SEAL (NONMETALLIC OR METALLIC)
GUIDE RODS
TANK SHELL
HINGED CENTER SUPPORT
NOZZLE
MANHOLE

FIGURE 2.1-13 - DIAGRAM OF A FLOATING ROOF TANK (EN-071)


Storage Tank(s)
Pipeline Gasoline
to Storage
*Storage Vapors to
Recovery Unit
Vent Gas
Vapor
Recovery
Unit
Loading Vapo s
to Recovery Unit
Terminal
Transport
Load-
ing
Rack
Gasoline to
Loading
Rack
Recovered
Gasoline

*In terminals using floating roof tanks, vapor lines from storage tanks to the vapor recovery unit are not required for the control of storage tank vapor losses.

FIGURE 2.1-14 - VAPOR AND LIQUID FLOW IN A TYPICAL BULK TERMINAL

2.1.3.3 Bulk Plants

Bulk loading stations are secondary distribution facilities which receive gasoline from bulk terminals by large tank trucks, store the gasoline in somewhat smaller above-ground storage tanks, and subsequently dispense the gasoline via smaller tank trucks to local farms, businesses, and service stations. Hydrocarbon emissions in bulk stations are generated from the storage tanks and from the tank truck loading operations. Emission factors mentioned previously for the loading of tank trucks at bulk terminals also apply to the hydrocarbon emissions generated during the loading of gasoline at bulk loading stations.

Because the storage tanks are often horizontal and cannot be fitted with floating roofs, or because they are below the size at which floating roof regulations apply, the storage tanks at bulk loading stations are generally uncontrolled and are thus a significant source of hydrocarbon emissions.

The emissions from storage tanks may be divided into two categories: breathing losses and working losses. Breathing losses are associated with the thermal expansion and contraction of the vapor space resulting from the daily temperature cycle. Working losses are associated with changes in the liquid level of the tank. Although the magnitude of these hydrocarbon emissions is dependent on numerous factors including tank parameters, Reid Vapor Pressure and weather conditions, they can be estimated by applying the appropriate emission factors. Figure 2.1-15 is a schematic drawing showing vapor and liquid flow through a typical bulk plant.

2.1.3.4 Service Stations

Service stations are the final facility in the gasoline marketing network. At the stations, gasoline is received by tank truck, stored in underground tanks, and dispensed to automobile fuel tanks. Unless a vapor collection system is provided, hydrocarbons in the storage tank vapor space are displaced as the tank is filled with gasoline from the tank truck. The quantity of these emissions is dependent on filling rate, filling method, Reid Vapor Pressure, and the system temperature.

Breathing losses from the underground gasoline storage tanks are another source of hydrocarbon emissions. The losses from underground service gasoline storage tanks has been estimated at 1 lb/1,000 gallons throughput (CA-155). Because the tanks are underground, breathing losses due to diurnal temperature effects are minimized.

Automobile refueling is the final source of hydrocarbon emissions from gasoline marketing operations. As with

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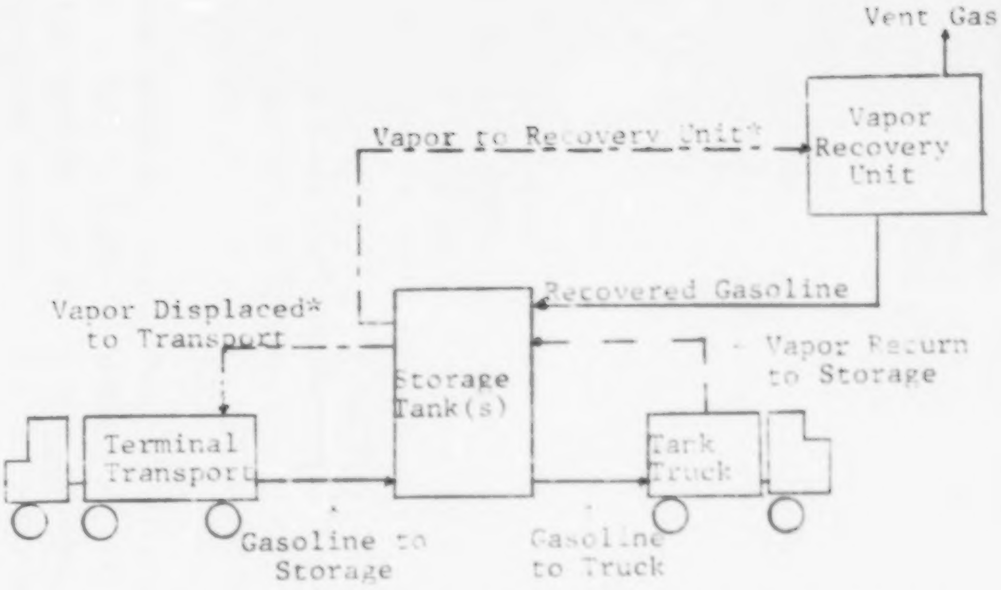

Vent Gas
Vapor Recovery Unit
Vapor to Recovery Unit*
Recovered Gasoline
Vapor Displaced* to Transport
Storage Tank(s)
Vapor Return to Storage
Terminal Transport
Tank Truck
Gasoline to Storage
Gasoline to Truck

*Vapor emissions from bulk plants may potentially be controlled by vapor displacement, in which case the recovery unit would be eliminated.

FIGURE 2.1-15 - VAPOR AND LIQUID FLOW IN A TYPICAL BULK PLANT

the filling of tank trucks or underground storage tanks, the hydrocarbon emissions are generated from the saturated gasoline vapors displaced as the fuel tank is filled. As previously mentioned, the quantity of these hydrocarbon emissions is dependent on the temperature and the Reid Vapor Pressure of the fuel. The uncontrolled emissions have, however, been estimated to be about 11 lbs/1,000 gallons of gasoline throughput. Figure 2.1-16 is a schematic drawing of vapor and liquid flow through a typical service station.

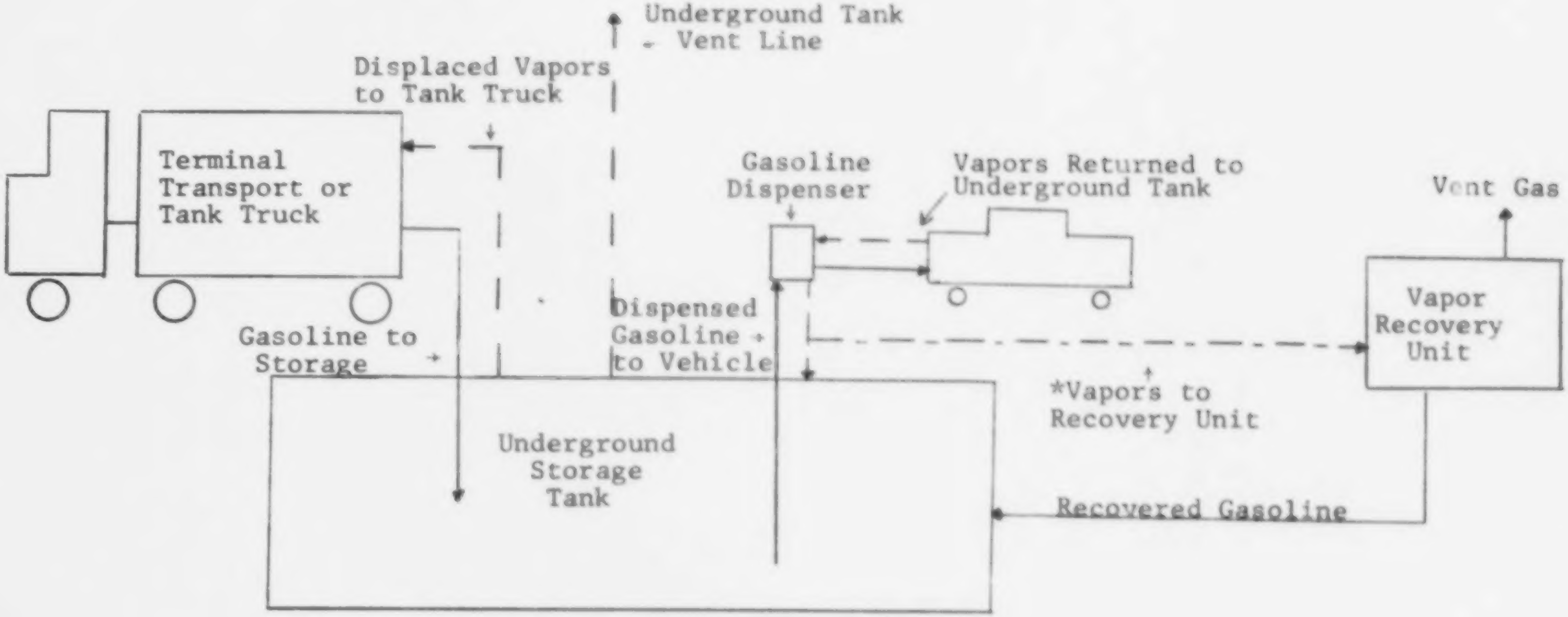
2.1.4 Uncontrolled Emissions

In uncontrolled bulk terminal, bulk plant, or service station operations, the vapors displaced by the liquid during tank fills contains hydrocarbons which are emitted to the atmosphere. The quantities of these emissions are variable, depending on such factors as the Reid Vapor Pressure of the gasoline, the method of loading, the temperatures of the vapors, and the effects of geographical and meteorological conditions.

The calculated quantity of uncontrolled emissions from average size terminals, bulk stations, and service stations are shown on the following pages. For purposes of illustration, a 250,000 gal/day bulk terminal, a 500,000 gal/month bulk station, and a 25,000 gal/month service station were sizes arbitrarily selected.

2.1.4.1 Bulk Terminals

Hydrocarbon emissions from bulk terminals come from either storage tanks or loading operations. Uncontrolled emissions from each of these sources will be considered separately.


Underground Tank
- Vent Line
Displaced Vapors
to Tank Truck
Terminal
Transport or
Tank Truck
Gasoline
Dispenser
Vapors Returned to
Underground Tank
Vent Gas
Dispensed
Gasoline
to Vehicle
Vapor
Recovery
Unit
Gasoline to
Storage
*Vapors to
Recovery Unit
Underground
Storage
Tank
Recovered Gasoline

*A service station controlling vapors by displacement will not have a vapor recovery unit.

FIGURE 2.1-16 - VAPOR AND LIQUID FLOW IN A TYPICAL SERVICE STATION

Storage Tank Losses

Two basic types of tanks are used in terminals: fixed roof tanks and floating roof tanks. Each of these basic tank designs may, however, have several modifications associated with it.

Fixed Roof Tanks

Fixed roof tanks are subject to both breathing and working losses. Breathing losses are associated with expansion and contraction of the vapor space resulting from the daily temperature cycle. Working losses are associated with changes in the liquid levels in the tanks.

Breathing Losses:

New tanks, 0.22 lb/day for 1000 gal capacity
Old tanks, 0.25 lb/day for 1000 gal capacity

Working Losses:

9 lb per 1000 gallon throughput (EN-071).

It is assumed that new tanks are all-welded and are vapor and liquid tight. Consequently, all breathing losses will occur through the tank vent. Some old tanks are riveted, and may have small leaks through which vapors can escape.

Floating Roof Tanks

Emissions from floating roof tanks come primarily from two sources: standing storage losses and wetting losses.

2.1.4.1 Bulk Terminals (Cont.)

Standing storage losses result from the improper fit of the seal and shoe to the tank shell and are the principal source of emissions of floating roof tanks. Wetting losses occur when a wetted tank wall is exposed to the atmosphere, but these are generally negligible.

Emission factors for hydrocarbon losses from floating roof tanks are:

New tanks, 0.033 lb/day per 1000 gal capacity
Old tanks, 0.088 lb/day per 1000 gal capacity

Old tanks are predicted to have greater emissions than new tanks predominantly because of inferior vapor seals on the floating roof. Riveted construction which is present on some older tanks will also contribute to higher vapor emissions.

By applying the above factors to the average terminal with an assumed 30 day storage capacity, the following uncontrolled emissions were determined.

	lb/day	gm/gal Throughput
1. Fixed Roof Tanks:		
a. New Tanks	3900	7.08
b. Old Tanks	4125	7.49
2. Floating Roof Tanks:		
a. New Tanks	249	0.45
b. Old Tanks	660	1.20

2.1.4.1 Bulk Terminals (Cont.)

Loading Operation Losses

During the loading operation vapor in the transport truck is displaced into the atmosphere as it is being filled from terminal storage. The amount of emissions generated is dependent primarily upon the type of loading operation.

There are two basic methods of filling transport tanks: top loading and bottom loading. The top loading procedure can be done with splash fill or submerged fill. With splash loading gasoline is discharged into the upper part of the tank compartment through a short spout which never dips below the surface of the liquid. The free fall of the gasoline droplets promotes evaporation and may even result in liquid entrainment of some gasoline droplets in the expelled vapors.

With subsurface or submerged loading, gasoline is discharged into the tank compartment below the surface of liquid in the tank. This is accomplished for top loading operations by the use of a long spout or fixed pipe extanding internally from the top tank entry to the bottom of the compartment. With direct bottom loading, transfer piping is connected directly to the tank bottom. This method achieves the same effect as submerged top loading while providing other advantages such as ease of loading operations and safety. Consequently, many terminals have already been converted to bottom loading.

The following hydrocarbon emission factors have been developed that approximate the amount of emissions generated by each of these loading operations (EN-071, AM-085):

Splash Loading: 12.4 lb/1000 gal transferred
Submerged Loading: 4.1 lb/1000 gal transferred
(top and bottom)

2.1.4.1 Bulk Terminals (Cont.)

Applying these factors to a 250,000 gallon per day terminal results in the following emissions from loading operations.

	lb/day	gm/gal Throughput
Splash Loading:	3100	5.63
Submerged Loading:	1025	1.85

The total uncontrolled emissions from a terminal can be estimated by summing the emissions attributable to tankage and to loading operations. For the worst possible case (old fixed roof tanks and splash loading) the uncontrolled emissions are 7225 lb/day (13.12 gm/gal throughput) and for the best case (new floating roof tanks and submerged or bottom loading) the uncontrolled emissions are 1272 lb/day (2.30 gm/gal throughput). Table 2.1-13 contains a tabulation of the amount of uncontrolled terminal emissions resulting from each of the possible combinations of equipment usage.

TABLE 2.1-13
UNCONTROLLED HYDROCARBON EMISSIONS FROM
250,000 GAL/DAY BULK TERMINAL

	Type of Truck Loading Operation			
	Splash Loading		Submerged Loading	
	lb/day	gm/gal	lb/day	gm/day
Fixed Roof Tanks:				
New Tanks	7000	12.71	4925	8.94
Old Tanks	7225	13.12	5159	9.35
Floating Roof Tanks:				
New Tanks	3347	6.08	1272	2.30
Old Tanks	3760	6.83	1685	3.06

2.1.4.2 Bulk Plants

Hydrocarbon emissions from bulk plants are also generated from the storage tanks and from the tank truck loading operations. Uncontrolled emissions from each source will be considered separately.

Storage Tank Losses

Because storage tanks typically found at bulk plants are relatively small, the use of floating roof tanks is not common. In many cases, horizontal tanks which cannot be fitted with floating roofs are used, and in others the tanks are not large enough to be subject to regulations. Therefore, only fixed roof tanks will be considered in the compilation of uncontrolled emissions from bulk plants.

The same emission factors used to predict the hydrocarbon emissions from terminal fixed roof tankage can be applied to bulk plants. The uncontrolled emissions for bulk plant tankage operations are based on storage capacity for 10 days of operation.

Estimated tankage emissions from a 500,000 gal/month bulk plant:

	lb/day	gm/gal Throughput
New Tanks:	186	5.09
Old Tanks:	191	5.22

Loading Operation Losses

As in terminal loading rack operations, both splash and submerged loading operations are used in bulk plants. Uncontrolled emissions for each type of loading operation at bulk stations have been compiled. The same emission factors as used for terminal loading operations are applicable to bulk plants.

The uncontrolled hydrocarbon emissions from a 500,000 gal/month bulk plant loading facility are:

Splash Loading: 206.7 lb/day (5.63 gm/gal)
Submerged loading: 68.3 lb/day (1.86/gm/gal)

Summing the emissions from tankage and loading operations results in the following total estimated uncontrolled emissions from bulk plants.

	Type of Truck Loading Operation			
	Splash Loading		Submerged Loading	
	lb/day	gm/gal	lb/day	gm/gal
New Tanks	393	10.71	255	6.95
Old Tanks	398	10.85	260	7.08

2.1.4.3 Service Stations

Uncontrolled emissions of hydrocarbons at service stations come from loading and unloading losses from tank trucks and underground tanks, refueling losses from vehicle tanks, and breathing losses from the underground tank vent.

Losses consist of: (1) organic liquid that evaporates into the air that is drawn in during withdrawal of the contents of a tank compartment, (2) losses from refilling the underground tank that results when the vapors are displaced from tank as it fills, (3) vapors displaced from vehicle tanks during refueling, and (4) underground tank breathing resulting from changes in vapor and liquid temperature.

Emission factors developed for these sources are as follows (EN-071, SC-167, CA-155):

1. Unloading: 1 lb/1000 gal gasoline transferred

2. Underground Tank Filling:

2.1.4.3 Service Stations (cont.)

Splash Filling: 11.5 lb/1000 gal transferred
Submerged Filling: 7.3 lb/1000 gal transferred

3. Vehicle Refueling: 11 lb/1000 gal dispensed

4. Underground Tank Breathing: 1 lb/1000 gal throughput

5. Spillage: 0.3 gm/gal dispensed

Applying these factors to the selected service station size of 25,000 gal/month throughput results in the following calculated uncontrolled emissions.

	lb/day	gm/gal Throughput
Unloading Losses:	0.83	0.45
Underground Tank Filling:		
Splash Filling:	9.6	5.22
Submerged Filling:	6.1	3.31
Vehicle Refueling:	9.2	5.0
Underground Tank Breathing:	0.83	0.45

Summing these values results in the following estimates for total uncontrolled emissions from a 25,000 gal/month service station.

	lb/day	gm/gal Throughput
1. With splash filling at underground tank:	20.46	11.15
2. With submerged filling at underground tank:	16.96	9.24

2.2 Emission Control Technology

2.2.1 Terminals

The emission control technology for bulk terminals is the most developed of those available to the gasoline marketing industry. Certain regions have for many years had regulations requiring emission controls and have thus encouraged the development of bulk terminal emission control technology. The petroleum industry has also viewed terminal control technology as an economical means of conserving valuable fuel products. This section outlines the control measures available for bulk terminal emissions, and compares such parameters as cost, efficiency, and reliability of these control systems.

2.2.1.1 Tankage Control Measures

Uncontrolled storage tanks (Figure 2.2-1) can account for half of the gasoline emissions from a bulk terminal. As detailed in Section 2.1.4, these tankage losses occur from breathing, evaporation, filling, emptying, and wetted walls. Bulk terminals apply two major approaches to controlling tankage losses; installing floating covers and installing variable vapor space tanks.

Floating Covers-Description

The purpose of equipping tanks with floating covers is the elimination of vapor spaces. This is accomplished by floating a rigid cover on the surface of the stored liquid. The roof then rises and falls according to the depth of stored liquid. The roof is equipped with a sliding seal at the tank wall to keep the liquid completely covered. With some floating covers, those termed floating roofs, no additional tank roof is required; however, many tanks are equipped with internal floating covers which also require a standard fixed tank roof.

2.2.1.1 Tankage Control Measures (cont.)

The three basic types of floating roofs are the pan, the pontoon, and the double deck. The simplest floating roof and the one with the longest history is the pan-type (Figure 2.2-2). This consists of a flat metal pan with a vertical rim and sufficient stiffening braces to maintain rigidity. The pan is sloped to the center where a flexible drain is provided for rain water. Although simple and relatively inexpensive, the pan floating roof is now seldom used. Tilting, holes, and heavy snows and rain loads have caused 20% (DA-069) of these roofs to sink. Also, the single metal plate in contact with the liquid readily conducts solar heat with resulting high vaporization losses.

In order to overcome the problem of sinking, the pan-type roof was modified by addition of pontoon sections to the top of the deck around the rim (Figure 2.2-3). The pontoons are arranged and compartmented to give good stability. Pontoon roofs are provided with drains similar to those used with pan roofs. Although the problem of roof stability is solved by the use of pontoons, the high vaporization losses resulting from solar heating are not noticeably reduced over those of the pan roof.

Extending the pontoon sections to completely cover the roof results in the double deck roof (Figure 2.2-4). The added expense of this design is generally considered to be justified by the added rigidity and by the insulation provided by the dead air space between the upper and lower deck plates. The compartmented dead air space is usually over one foot deep and provides enough insulation to significantly reduce vapor losses. Rain water is removed through a flexible drain pipe.

The most common form of internal floating cover is the internal pan (Figure 2.2-5). Since the fixed roof protects the floating roof from the weather, no provision is required

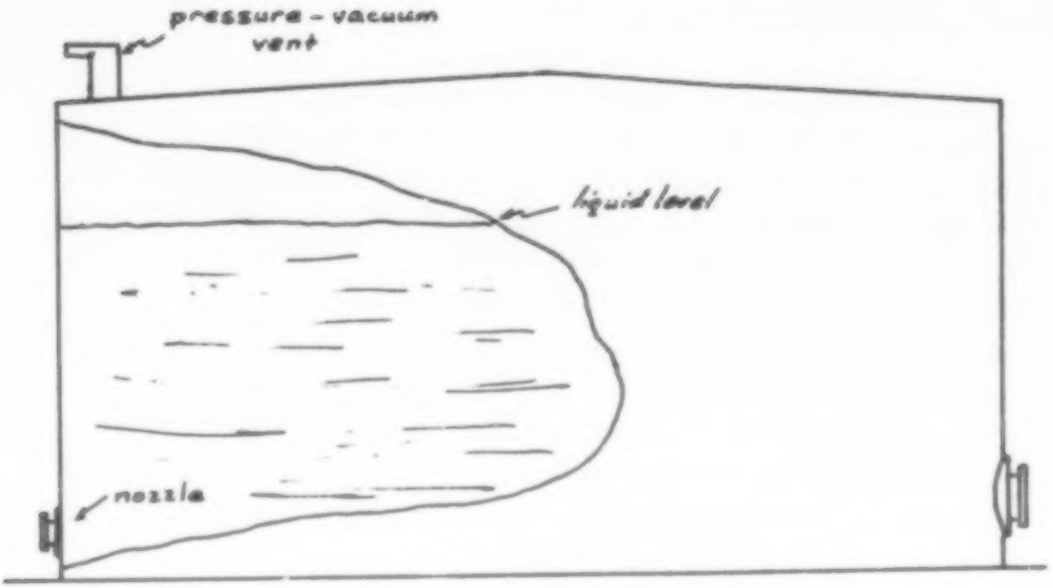

pressure - vacuum vent
liquid level
nozzle

FIGURE 2.2-1 - STANDARD FIXED CONE ROOF TANKS

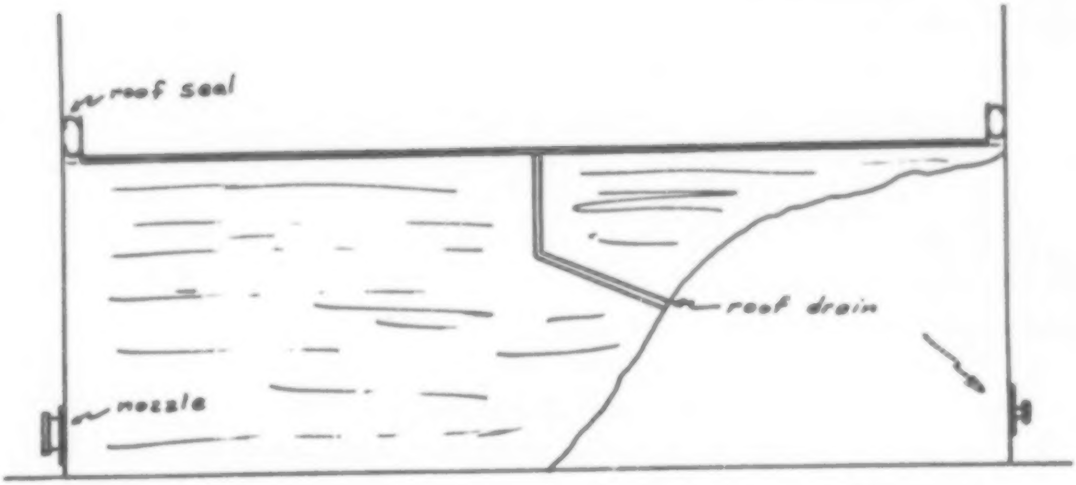

roof seal
roof drain
nozzle

FIGURE 2.2-2 - PAN-TYPE FLOATING ROOF TANK

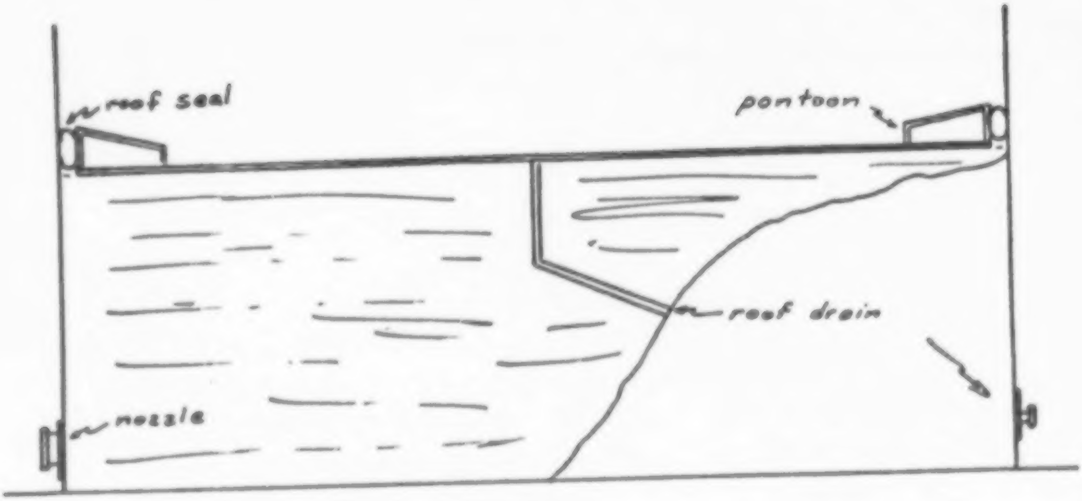

roof seal
pontoon
roof drain
nozzle

FIGURE 2.2-3 - PONTOON FLOATING ROOF TANK

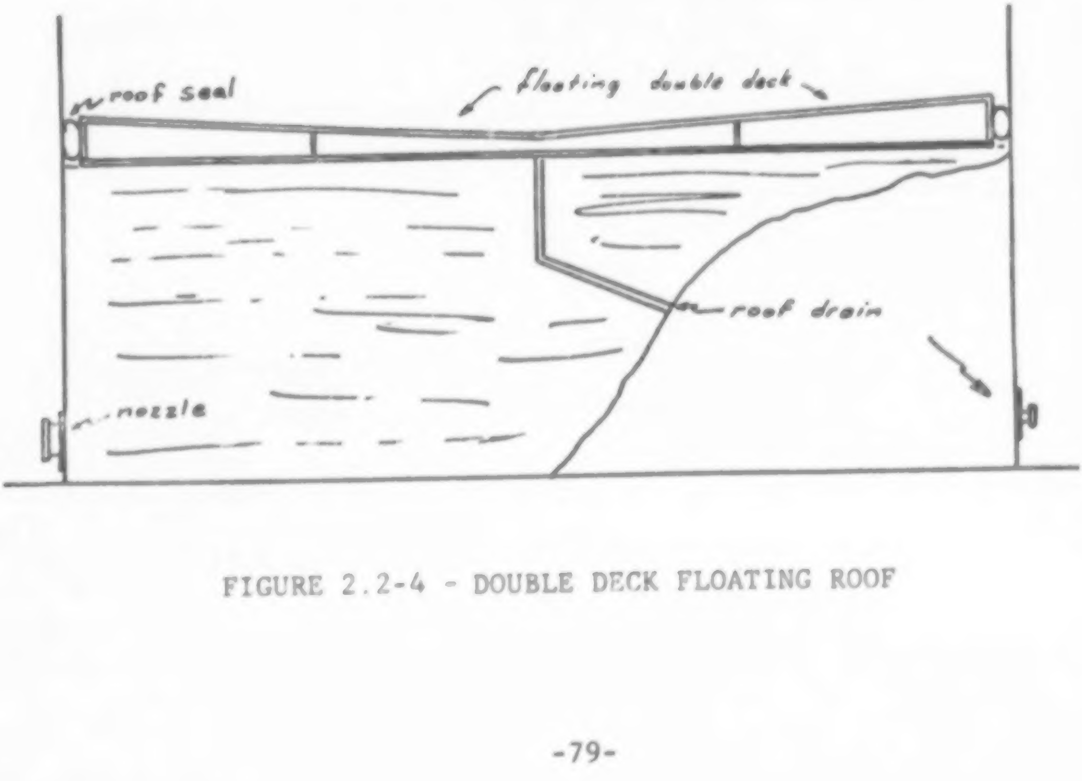

roof seal
floating double deck
roof drain
nozzle

FIGURE 2.2-4 - DOUBLE DECK FLOATING ROOF

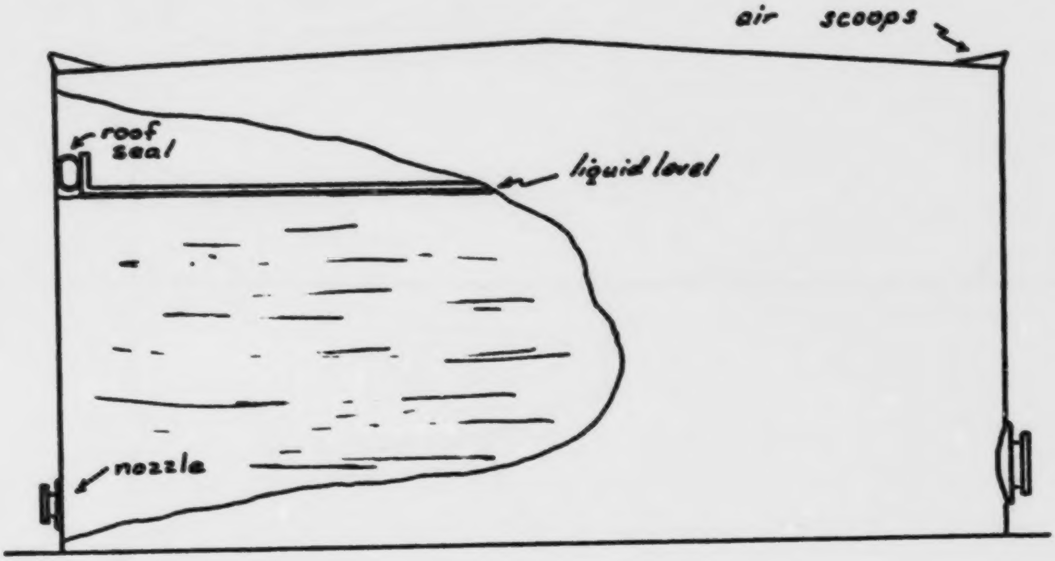

air scoops
roof seal
liquid level
nozzle

FIGURE 2.2-5 - PAN-TYPE INTERNAL FLOATING COVER

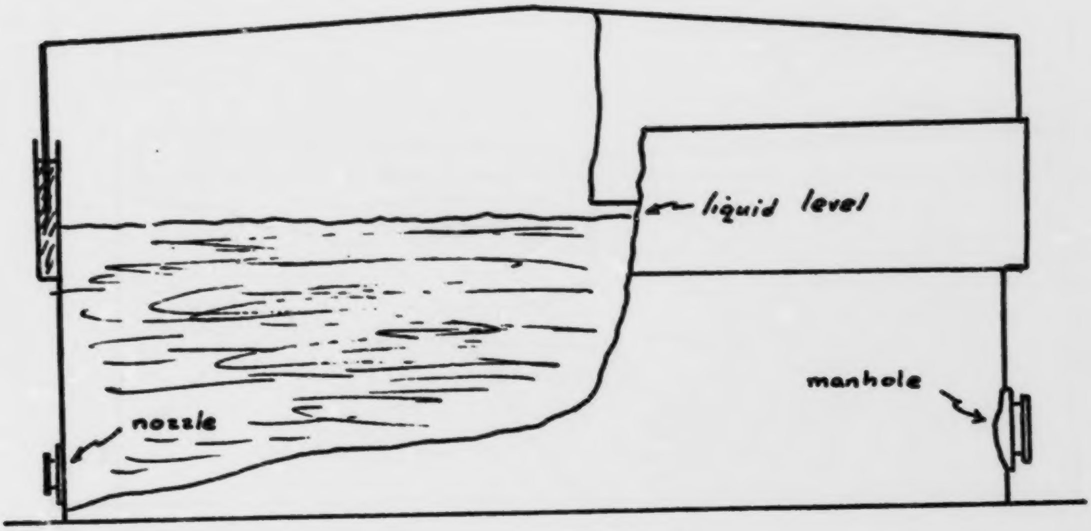

liquid level
manhole
nozzle

FIGURE 2.2-6 - LIFTER ROOF TANK

for rain water removal. Maintenance is reduced since the internals, particularly the seals, are protected from the weather and the product is less likely to be contaminated by dirt or water. Existing fixed roof tanks can be converted to internal floating covers without difficulty.

Sliding seals are an important feature of all floating roofs. The ideal seal is vapor tight, long-lasting, and requires little maintenance. The seals play a significant role in determining the effectiveness of floating covers.

Floating Covers-Efficiency

The efficiency of floating covers varies depending on the condition of the storage tank and its sliding seals. Section 2.1.4 details the calculational procedure for determining the emission reduction from replacing uncontrolled fixed roof tanks with floating covers. The efficiency of floating covers 95%, and product recovery alone is sufficient to justify the cost expenditure.

Floating Covers-Cost

The costs associated with storage tanks and floating covers are continually rising, complicating cost analysis studies. Table 2.2-1 attempts to summarize current installed and annual operating cost ranges for a 90' diameter 50,000 bbl storage tank. The overall economics of storage tanks is presented in detail in Section 3.6. Due to the high value of gasoline, the yearly return on investment is greater than 30% for all types of floating covers.

TABLE 2.2-1

SUMMARY OF STORAGE TANK COSTS

(Basis: 50,000 bbl storage tank, 90' diameter)

	Installed Cost	Annual Operating Cost
Fixed Roof	\$118,000-\$161,000	\$29,900
Pontoon Floating Roof	\$146,000-\$176,000	\$25,500
Internal Floating Cover	\$146,000-\$210,000	\$28,600
Retrofit Floating Cover In Existing Fixed Roof	\$ 20,000-\$ 40,000	-

2.2.1.1 Tankage Control Measures (Cont.)

Floating Covers-Safety

The safety of floating covers with regard to fire and explosions is very good. Fires in floating roof tanks tend to occur only along the sliding seal where they can be easily extinguished. Minor seal and deck leaks can cause explosive mixtures over internal floating covers. To alleviate this problem, air scoops are installed in the cone roofs over internal floating covers for prevention of air stagnation. External floating roofs are also subject to drainage and bouyancy problems under water and snow loads. The greater bouyancy of pontoon and double deck floating roofs and the cone roof covering internal floating covers greatly reduce the hazard of floating covers sinking.

Variable Vapor Space Tanks-Description

The objective in employing a variable vapor space tank at a bulk terminal is to provide storage for vapor emissions until they can be processed in a vapor recovery unit. The variable vapor space tank is manifolded to the vapor space of the fixed roof tanks, the loading rack, and the vapor recovery unit through a vapor gathering system (Figure 2.2-7). Expanded and displaced vapors are stored in the variable vapor space, then sent to the vapor recovery unit when the vapor holder is filled. The two basic types of variable vapor space tanks employed at bulk terminals are lifter roof tanks and flexible diaphragm tanks.

Lifter roof tanks normally are used for liquid storage and to provide a variable vapor space. The roof of the tank has a dip skirt that fits loosely around the outside of the main tank wall. The space between the skirt and the wall is closed

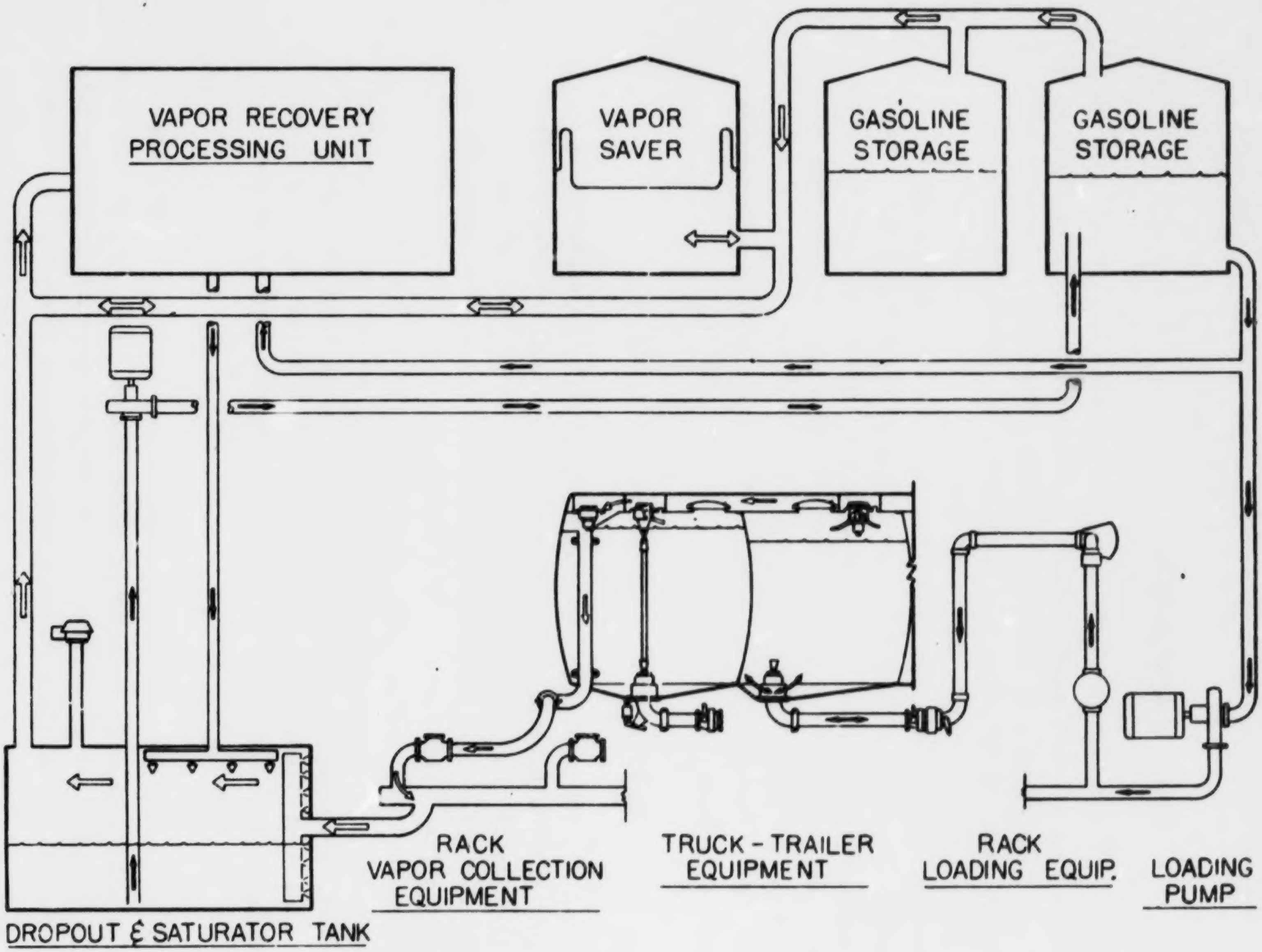

VAPOR RECOVERY PROCESSING UNIT
VAPOR SAVER
GASOLINE STORAGE
GASOLINE STORAGE
RACK VAPOR COLLECTION EQUIPMENT
TRUCK - TRAILER EQUIPMENT
RACK LOADING EQUIP.
LOADING PUMP
DROPOUT & SATURATOR TANK

FIGURE 2.2-7 - INTEGRATED VAPOR GATHERING SYSTEM

by either a wet or a dry seal (Figure 2.2-6). Usually the tanks are designed for a five- or ten-foot lift. When the lifter roof tank is manifolded to fixed roof tanks as part of a vapor gathering system, the operating pressure of the lifter roof sets the operating pressure of the entire system. The operating pressure of lifter roof tanks ranges from 2.5 to 7 inches of water, depending on the design. This is often in excess of the recommended working pressure for fixed roof tanks. However, fixed roof tanks can be designed or modified to withstand the higher pressure.

Flexible diaphragm tanks can be integral units, serving much the same purpose as lifter roof tanks (Figure 2 2-8) or they can be installed as separate units to serve as variable vapor spaces only (Figure 2.2-9). The outer tank can be either cylindrical or spherical with a plastic or rubberized fabric diaphragm fastened to the wall midway up. Since the diaphragm is lighter than a steel roof, the operating pressure of these tanks is lower than that for lifter roof tanks. An operating pressure of 0.8 inches [illegible] water is normal and is less than that of most fixed roof tanks.

Variable Vapor Space Tanks-Efficiency

Because variable vapor space tanks and the manifolded fixed roof tanks are sealed from the atmosphere, there are virtually no direct tankage emissions. When the vapor saver is full the vapors are sent to a vapor recovery processing unit. Overall vapor recovery efficiency in this system is dependent on the efficiency of the processing unit.

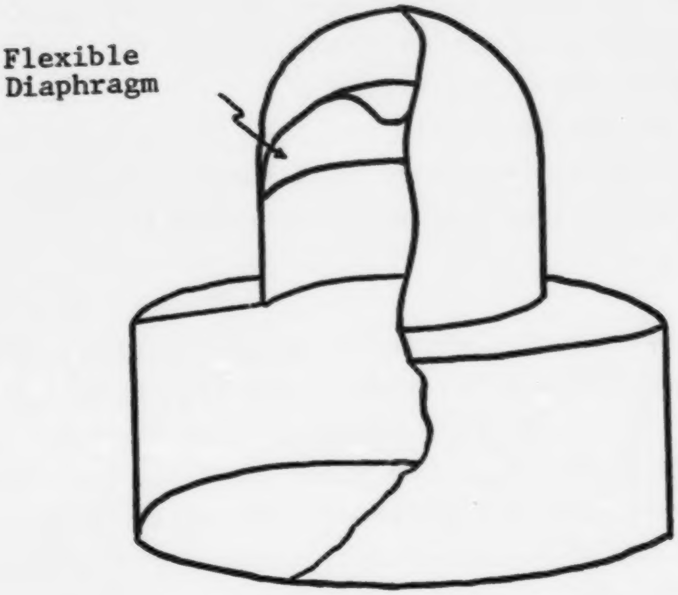

Flexible
Diaphragm

FIGURE 2.2-8 - COMBINED STORAGE TANK AND FLEXIBLE DIAPHRAGM

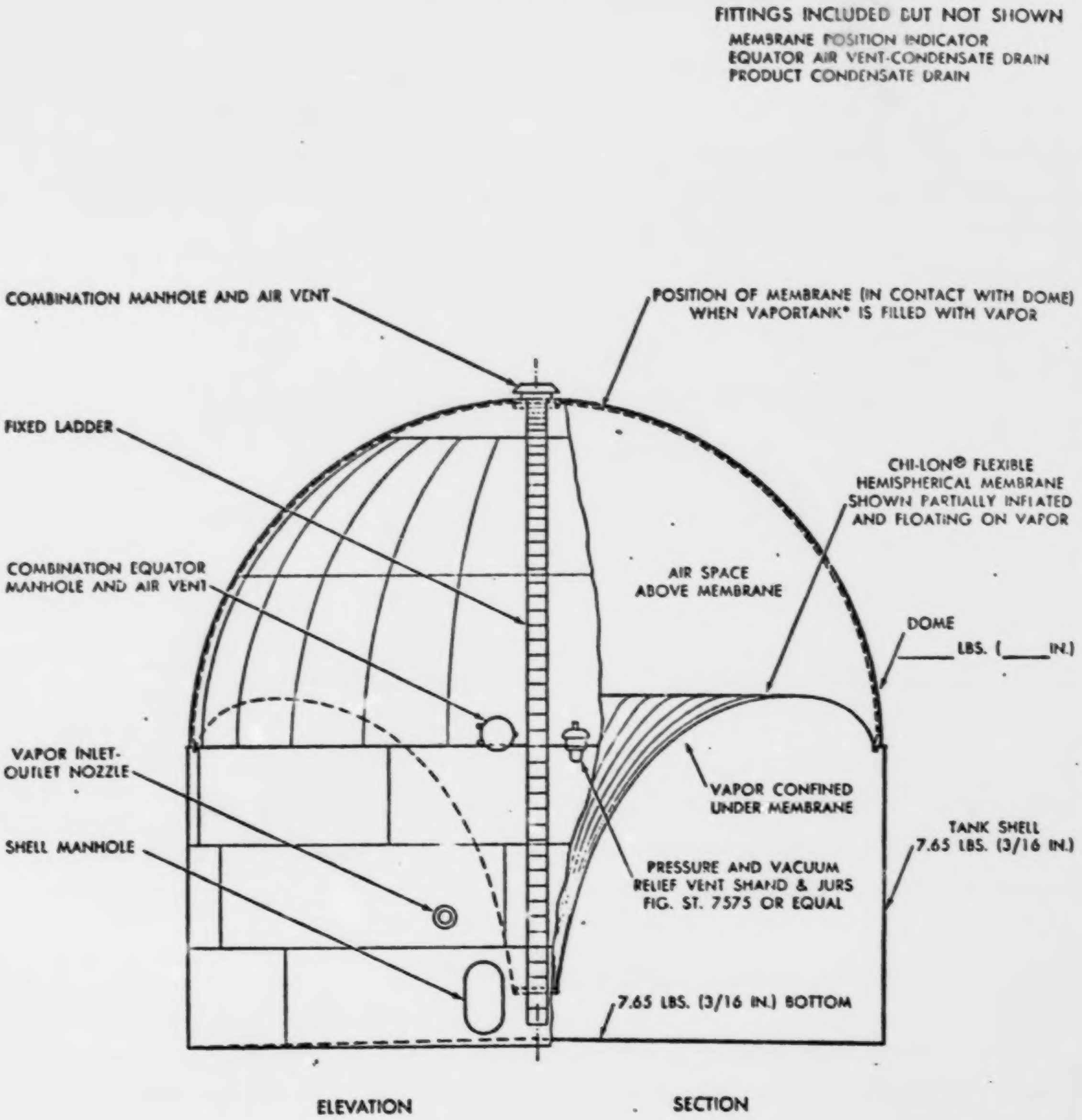

FITTINGS INCLUDED BUT NOT SHOWN
MEMBRANE POSITION INDICATOR
EQUATOR AIR VENT-CONDENSATE DRAIN
PRODUCT CONDENSATE DRAIN
COMBINATION MANHOLE AND AIR VENT
POSITION OF MEMBRANE (IN CONTACT WITH DOME) WHEN VAPORTANK* IS FILLED WITH VAPOR
FIXED LADDER
CHI-LON® FLEXIBLE HEMISPHERICAL MEMBRANE SHOWN PARTIALLY INFLATED AND FLOATING ON VAPOR
COMBINATION EQUATOR MANHOLE AND AIR VENT
AIR SPACE ABOVE MEMBRANE
DOME
_____ LBS. (_____ IN.)
VAPOR INLET-OUTLET NOZZLE
VAPOR CONFINED UNDER MEMBRANE
TANK SHELL
7.65 LBS. (3/16 IN.)
SHELL MANHOLE
PRESSURE AND VACUUM RELIEF VENT SHAND & JURS FIG. ST. 7575 OR EQUAL
7.65 LBS. (3/16 IN.) BOTTOM
ELEVATION
SECTION

FIGURE 2.2-9 - INDEPENDENT FLEXIBLE DIAPHRAGM TANK

2.2.1.1 Tankage Control Measures (Cont.)

Variable Vapor Space Tanks-Cost

The installed cost ranges for variable vapor space tanks is presented below in Table 2.2.-2 (DA-069). These prices are vendor quotes from 1961 and have probably escalated significantly. More detailed cost breakdowns are presented in the cost section (Section 3.6) of this report.

TABLE 2.2-2

INSTALLED COSTS FOR VARIABLE VAPOR SPACE TANKS

(50,000 bbl-1961)

Lifter Roof 5'	$68,000- $80,000
Lifter Roof 10'	$81,000- $92,000
Flexible Diaphragm	$80,000-$105,000

Some vapor recovery units require vapor holders and the economics of variable vapor space tanks are improved by saving the purchase of the vapor holder.

Variable Vapor Space Tanks-Safety

Properly maintained variable vapor space tanks are virtually vapor tight and dangers of fire and explosion are minimal. Flame arresters are normally installed in safety relief valves and vapor return lines. Dangerous explosive mixtures in the domes above flexible diaphragms can result from vapor leaks, but these can be eliminated through regular maintenance.

Summary

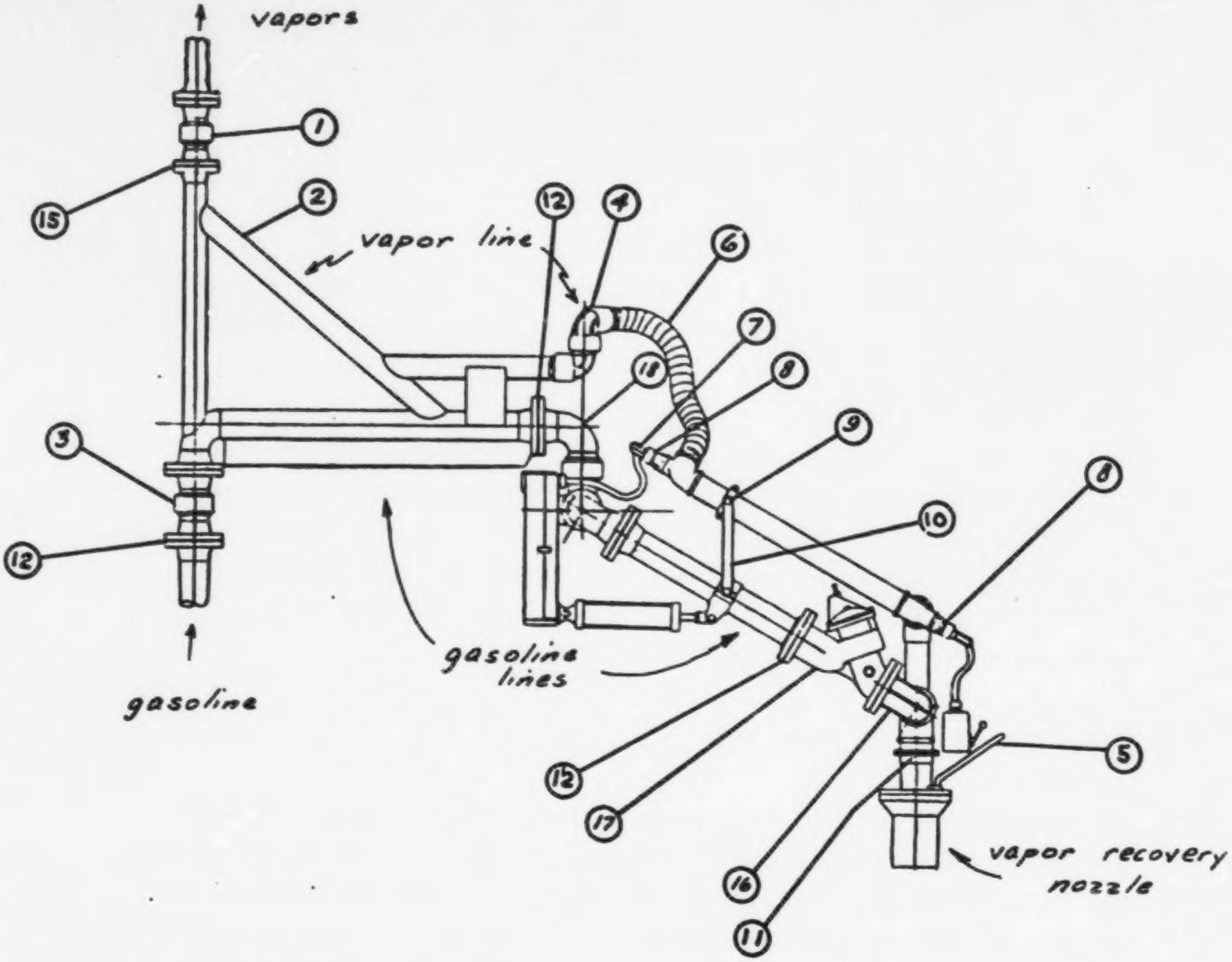
In summary, there are two major approaches to controlling hydrocarbon emissions from bulk terminal tankages. The first to float a rigid cover on the surface of the stored gasoline, thus eliminating the vapor space. The second approach is to contain the tankage vapors within a sealed tank system incorporating a variable vapor space tank to act as surge capacity. The efficiency of these two approaches in the control of tankage emissions is greater than 90% over uncontrolled tankage losses. The value of recovered gasoline has justified the cost of the tankage control systems described above.

2.2.1.2 Loading Rack Vapor Controls

A second source of emissions from bulk terminals occurs at the tank truck loading rack. As the truck is loaded, gasoline vapors in the tank, unless contained, are displaced to the atmosphere. These emissions were quantified in Section 2.1.4. They are dependent on the previous drop made by the truck, the method of gasoline loading, and climatic conditions. Loading rack vapor control equipment attempts to capture these emissions and transfer them to the loading rack. At the loading rack they are combined with the vapors from other truck positions and piped to a vapor recovery unit. This section reviews the cost and efficiency of loading rack controls.

Description

The type of vapor collection system at the truck rack depends on how the truck is loaded. If the truck is top loaded, vapors are recovered through a top loading arm (Figure 2.2-10).


vapors
①
⑮
②
vapor line
⑫
④
⑥
⑦
⑱
⑧
⑨
③
⑩
⑧
⑫
gasoline lines
gasoline
⑤
⑫
⑰
⑯
⑪
vapor recovery nozzle

MISCELLANEOUS PARTS

ITEM	PART NO.	DESCRIPTION	QTY.
1	3420-F-30	Swivel Joint, 3"	1
2	2775 *	Boom	1
3	3420-F-40	Swivel Joint, 4"	1
4	H-5936	Swivel Joint 3"	1
5	D-837-M	Handle	1
6	H-5898-RP	Hose	1
7	H-5906-M	Elbow	1
8	H-5905-M	Cord Grip	2
9	H-5818-	Collar Sub-Assembly	2
10	C-1667-A	Link	2
11	C-2479-M	Gasket	1
12	H-4190-M	Gasket, 4"	6
13	D-836-M	Upper Handle & Pipe	1
14	3630-30	Swivel Joint, 3"	1
15	H-4189-M	Gasket, 3"	1
16	H-5952	Swivel Joint Sub-Assembly, 4"	
	3840-FO-40	Swivel Joint Only	1
	710	4 x 2 7/8 Nipple Only	1
	C-555-A	4" Flange Only	1
17	417-FKA-4"	Loading Valve	1
18	3476-F-40	Swivel Joint, 4"	1

FIGURE 2.2-10 - TOP LOADING ARM EQUIPPED WITH A VAPOR RECOVERY NOZZLE

Top loading arms consist of a splash or submerged loading nozzle (Figure 2.2-11) fitted with a head which seals tightly against the hatch opening. Gasoline is loaded through a central channel in the nozzle. Displaced vapors flow into an annular vapor space surrounding the central channel and in turn flow into a hose leading to a vapor recovery system. Since the vapor line is incapable of handling liquid overflows a safety shut-off is usually included in the nozzle. Some of the advantages of top loading vapor collection are:

- there are minimal, if any, modifications required for existing top loading trucks,
- it is relatively inexpensive to convert existing top loading racks for vapor recovery, and
- they are adaptable to existing top loading independent carriers.

Top loading vapor collection, however, is not compatible with trucks equpped for vapor displacement at service stations.

If the truck is bottom loaded, then the equipment needed to recover the vapor is considerably less complicated. Vapor and liquid lines are independent of each other with resultant simplification of design. Figure 2.2-12 shows a typical installation. The vents on top of the trucks are manifolded together and a single vapor vent line is brought from the truck near the bottom loading fueling connections. One or both of the truck turnover rails are usually used as the vapor manifold. Vapor collection and gasoline dispensing lines are flexible hoses and/or swing-type arms connected to quick acting couplings on the truck.

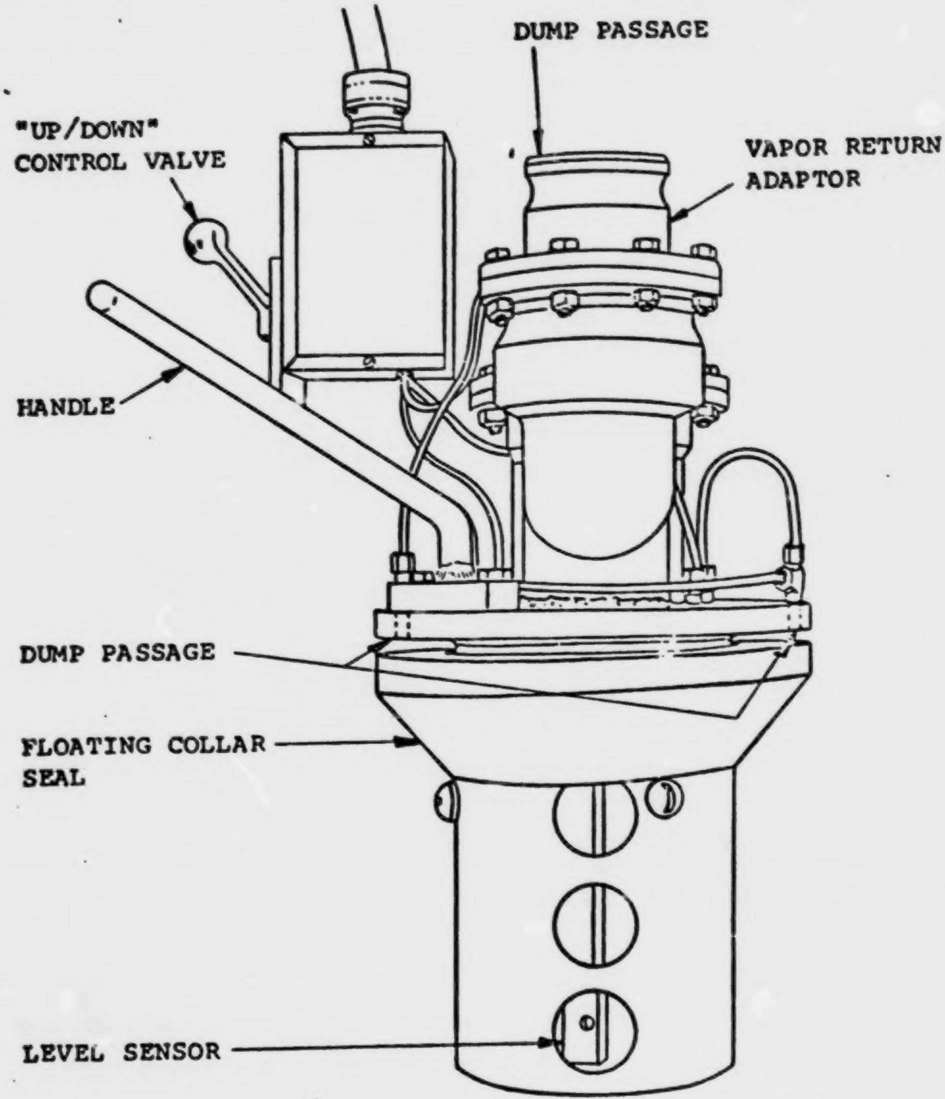

DUMP PASSAGE
"UP/DOWN" CONTROL VALVE
VAPOR RETURN ADAPTOR
HANDLE
DUMP PASSAGE
FLOATING COLLAR SEAL
LEVEL SENSOR

FIGURE 2.2-11 DETAIL OF A VAPOR RECOVERY NOZZLE

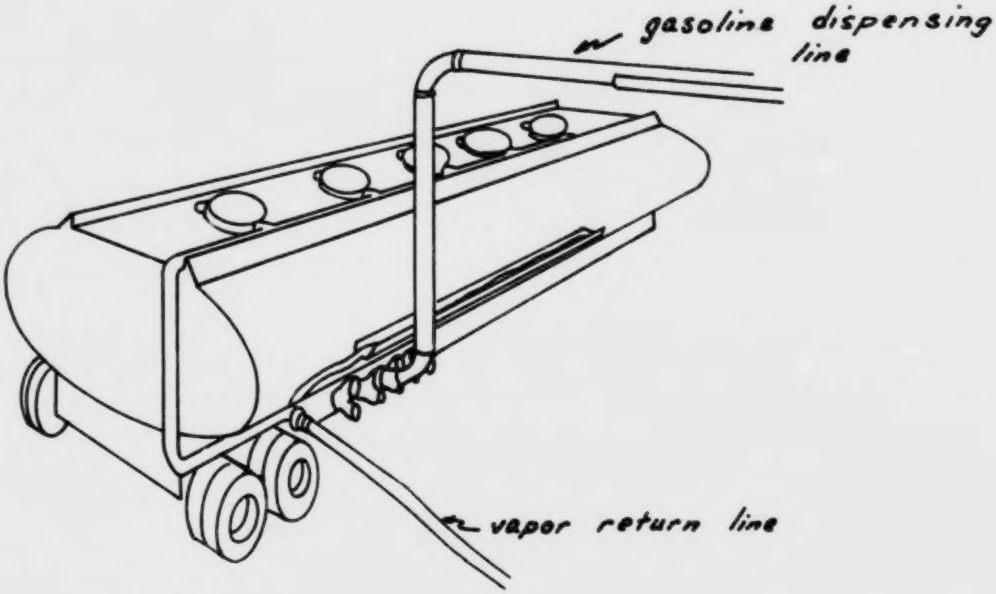

gasoline dispensing line
vapor return line

FIGURE 2.2-12 - BOTTOM LOADING VAPOR RECOVERY

Bottom loading vapor recovery has many advantages over top loading vapor recovery. The operator does not have to walk on top of the truck. Bottom loading generates much less vapor, generates almost no mist, and is safter from a static electricity point of view. Because of the capacity to simultaneously load several compartments, bottom loading allows faster loading. In addition, a truck equipped to pick up vapors at the service station is equipped for bottom loading.

Efficiency

The vapor containment efficiency of bottom loading equipment may approach 100% if there are no leaks in the truck. When properly operating, the system remains sealed throughout the loading operation. Dry break couplings are used on the gasoline dispensing lines and check valves are used on the vapor return lines to minimize spills and vapor escape during hook-ups and disconnects.

Although difficult to quantify the vapor collection efficiency for top loading is lower than for bottom loading. Vapors escape from the hatch opening during insertion and removal of the top loading nozzle. There are also losses due to spills as the loading arm is raised from the truck.

Cost

FOB costs for 4-inch top loading vapor collection arm assemblies, including nozzles, range from $2,000 to $3,000 (1974, AM-055 and BR-163). FOB costs for bottom loading vapor collection equipment range from $1,000 to $3,000 (BR-163), depending on whether simple flexible hoses or complex counter balance loading arms are employed.

A standard 250,000 gpd bulk terminal will have approximately two loading racks with three loading arms each, for a total of six loading arms. The cost of equipping such a terminal with top loading vapor collection arms would be $15,000 and with bottom loading vapor collection arms would be $12,000.

Reliability

The safety and reliability of vapor collection equipment for loading racks is extremely good. Technology in this area is well advanced because the petroleum industry has applied vapor collection equipment on gasoline and other volatile product loading facilities for many years.

Summary

In summary, there are two basic types of vapor collection systems for truck loading racks, top loading and bottom loading. Although top loading vapor collection systems require only minimal inexpensive modifications to existing top loading trucks and loading racks, the trend is to go to bottom loading vapor collection because of the reduction in generated vapors and its compatibility with trucks equipped to pick up vapors at service stations. The collection efficiency of both types of loading rack vapor collection systems approaches 100% for leak free truck tanks. FOB costs for top loading vapor collection assemblies range from $2,000 to $3,000 and for loading vapor collection equipment range from $1,000 to $3,000.

2.2.1.3 Vapor Recovery Units

Vapor recovery units are manifolded into the vapor collection system at bulk terminals for either conversion of the gasoline vapors into liquid product or for disposal of the vapors through such processes as combustion or adsorption. Figure 2.2-7 shows an integrated vapor collection system channeling excess vapors from the loading rack and the gasoline tankage to the vapor recovery unit. This section reviews the vapor recovery systems applicable to bulk terminals and assesses the efficiency, cost, reliability, safety and manufacturing capacity of these systems. A 250,000 gpd bulk terminal was chosen as the basis for cost comparisons.

Compression-Refrigeration-Absorption Systems

The compression-refrigeration-absorption vapor recovery system (CRA) is based on the absorption of gasoline vapors under pressure with cool gasoline from storage. The primary unit in CRA systems is the absorber with the remaining components serving to condition the vapor and liquid entering the absorber, improve absorber efficiency, reduce thermal losses, and/or improve system safety. Figures 2.2-13 and 2.2-14 show two CRA vapor recovery systems. Incoming vapors are first passed through a saturator where they are sprayed with fuel to insure that the hydrocarbon concentration of the vapors is above the explosive level. This is done as a safety measure to reduce the hazards of compressing hydrocarbon vapors.

The partially saturated vapors are then compressed and cooled prior to entering the absorber. In the absorber the cooled, compressed vapors are contacted by chilled gasoline drawn from product storage and are absorbed. The remaining air containing only a small amount of hydrocarbons is vented from the top of the absorber and gasoline enriched with light ends is withdrawn from the bottom of the absorber and returned to the fuel storage tanks. The operating conditions in the absorber

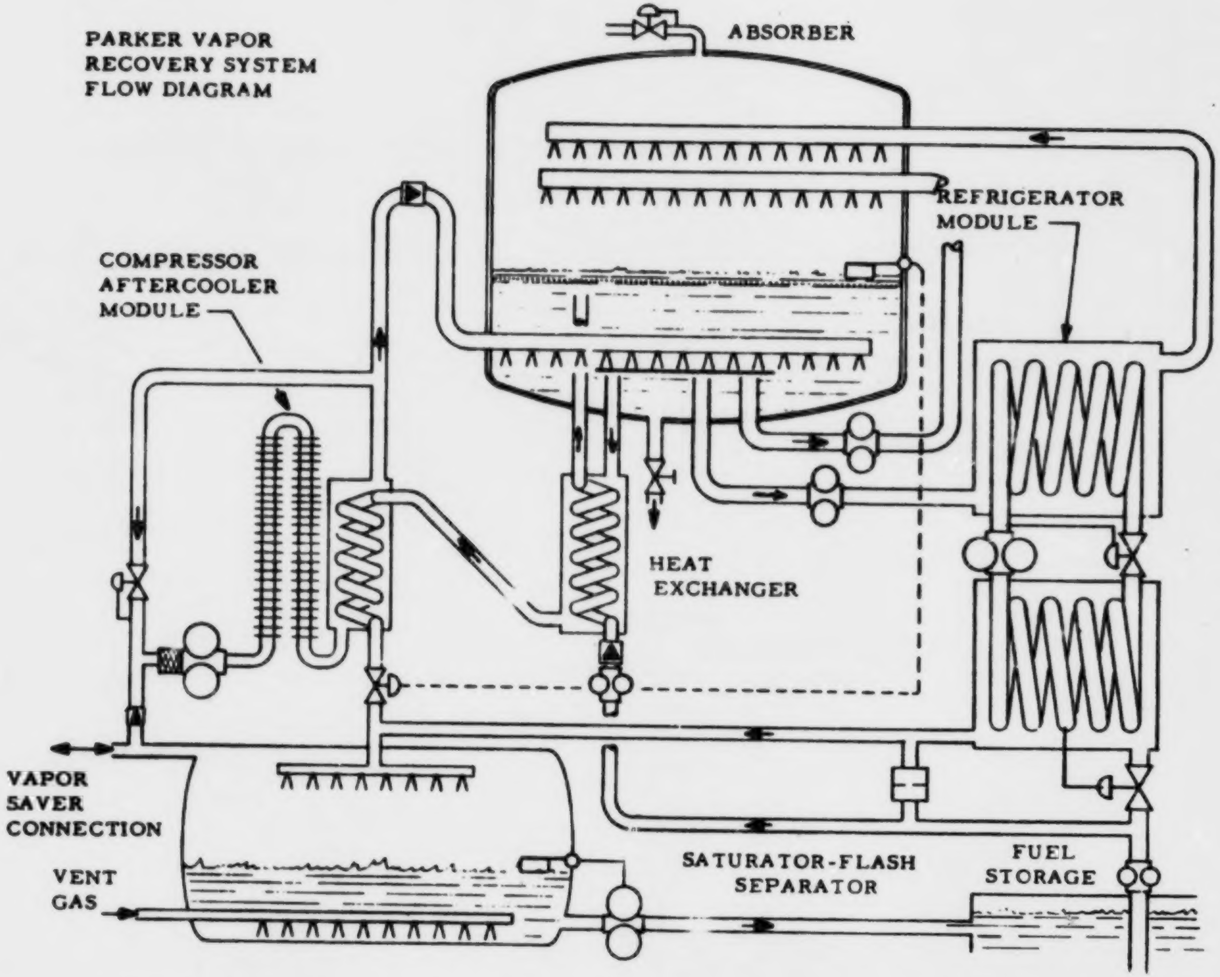

PARKER VAPOR
RECOVERY SYSTEM
FLOW DIAGRAM
ABSORBER
REFRIGERATOR
MODULE
COMPRESSOR
AFTERCOOLER
MODULE
HEAT
EXCHANGER
VAPOR
SAVER
CONNECTION
VENT
GAS
SATURATOR-FLASH
SEPARATOR
FUEL
STORAGE

FIGURE 2.2-13 - COMPRESSION-REFRIGERATION-ABSORPTION UNIT BY PARKER HANNIFIN

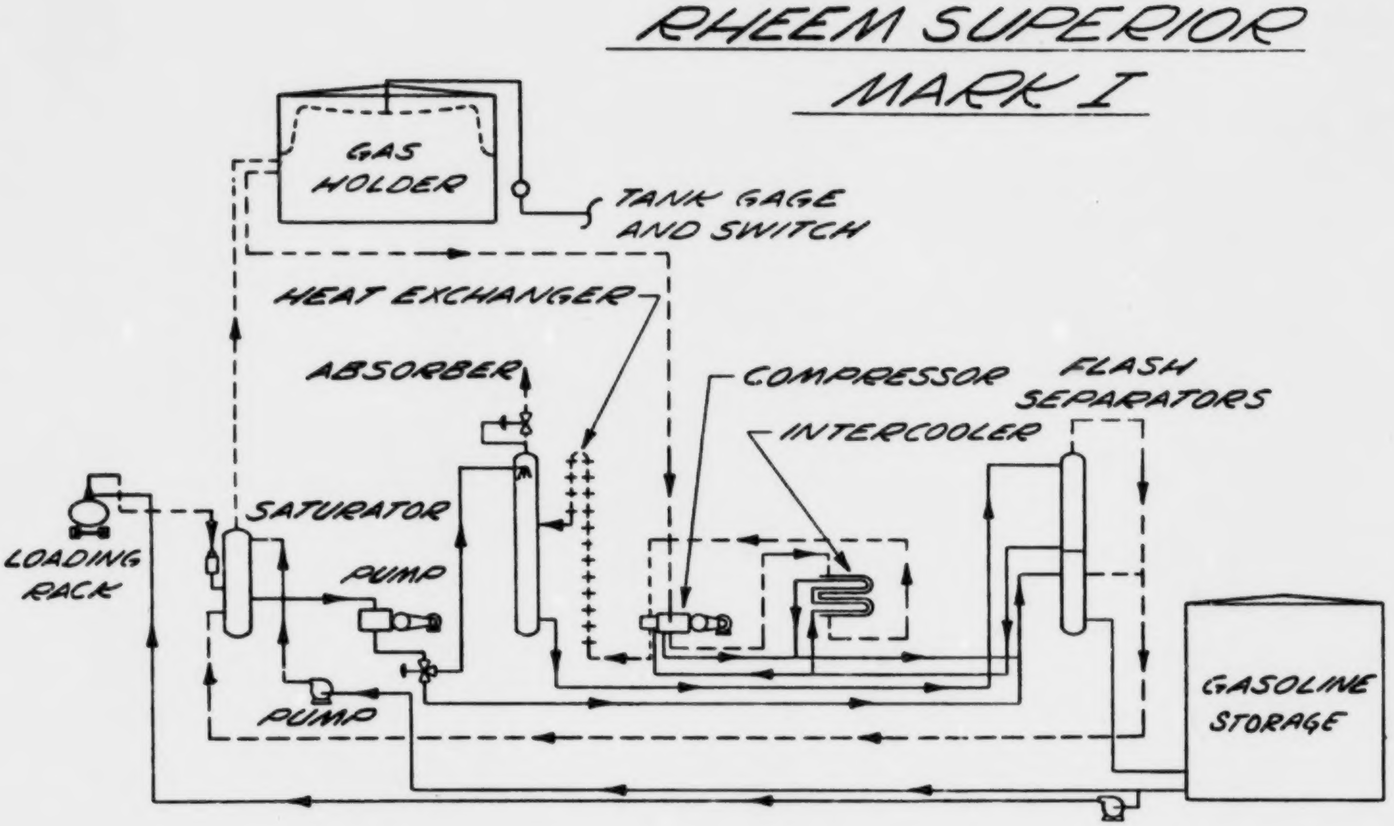

RHEEM SUPERIOR
MARK I
GAS HOLDER
TANK GAGE AND SWITCH
HEAT EXCHANGER
ABSORBER
COMPRESSOR
FLASH SEPARATORS
INTERCOOLER
SATURATOR
PUMP
LOADING RACK
PUMP
GASOLINE STORAGE

FIGURE 2.2-14 - COMPRESSION-REFRIGERATION-ABSORPTION UNIT BY RHEEM SUPERIOR

2.2.1.3 Vapor Recovery Units (Cont.)

vary with the manufacturer, and range from -10° F to ambient temperature and from 45 psig to 210 psig.

Although dependent on terminal operating schedules and vapor storage capacity, for cost estimating purposes, it has been assumed that a 250,000 gpd terminal will require a 150 CFM vapor recovery unit. The FOB cost of a 150 CFM CRA unit ranges from $83,000 to $90,000. Yearly maintenance and operating costs have been estimated at 2% to 3% of the capital cost or $1,660 to $2,700. Installation and site preparation cost estimates range from $25,000 to $80,000, depending on vapor holder requirements. Terminals employing variable vapor space storage tanks will not require vapor holders. Utility costs depend on power rates. Power requirements for CRA vapor recovery units are approximately 7.4 to 10.7 horsepower/1000 CF or 250 to 360 kwh/day for the sizes described above.

The vapor collection efficiency of a CRA vapor recovery unit is difficult to define due to its dependency on inlet hydrocarbon concentration. The outlet hydrocarbon concentration, however, is essentially fixed by the absorber operating conditions. Field tests have shown it to range from 1% to 4.5% by volume. Current CRA systems on the market can surpass 90% recovery (if so required) for inlet hydrocarbon concentrations of greater than 20% by volume. One CRA unit supplies a booster compressor to achieve 90% recovery at lower inlet hydrocarbon concentrations.

Compression-Refrigeration-Condensation Systems

Compression-Refrigeration-Condensation vapor recovery systems (CRC) were the first type utilized by the petroleum industry. They are based on the condensation of hydrocarbon vapors by compression and refrigeration. Figures 2.2-15 and 2.2-16 show the flow scheme of two CRC systems. Incoming vapors are first contacted with recovered product in a saturator, and are saturated beyond the flamability range. The saturated vapors are then compressed in a two-stage compressor with an inter-cooler. Condensate is withdrawn from the inter-cooler prior to second stage compression. The compressed vapors pass through a condenser where they are cooled, condensed, and returned along with condensate from the inter-cooler to the gasoline storage tank. Essentially, hydrocarbon-free air is vented from the top of the condenser. Each manufacturer has minor variations from this basic flow scheme. Operation conditions vary with the manufacturer, with temperatures ranging from -10°F to 30°F and pressures ranging from 85 psig to 410 psig.

Although dependent on terminal operating schedules and vapor storage capacity for purposes of cost evaluation, it has been assumed that a 250,000 gpd terminal will require a 150 CFM vapor recovery unit. The FOB cost for a 150 CFM CRC unit ranges from $80,000 to $100,000. The unit costing $80,000 also requires a vapor holder which for this size unit ranges in cost from $8,000 to $20,000. Site preparation and installation cost estimates range from $5,000 to $25,000, excluding vapor holder costs. Utility costs depend primarily on power rates. Power requirements for CRC vapor recovery units are approximately 11 hph/1000 CF or 370 kwh/day for the size described above. Overall yearly operating and maintenance costs are estimated at 2% to 3% of the capital cost or $2,000 to $3,000.

The efficiencies of CRC vapor recovery units are not well documented and difficult to define due to their dependency on inlet hydrocarbon concentrations. Data from field tests indicate that CRC units can recover 96% of the hydrocarbons in

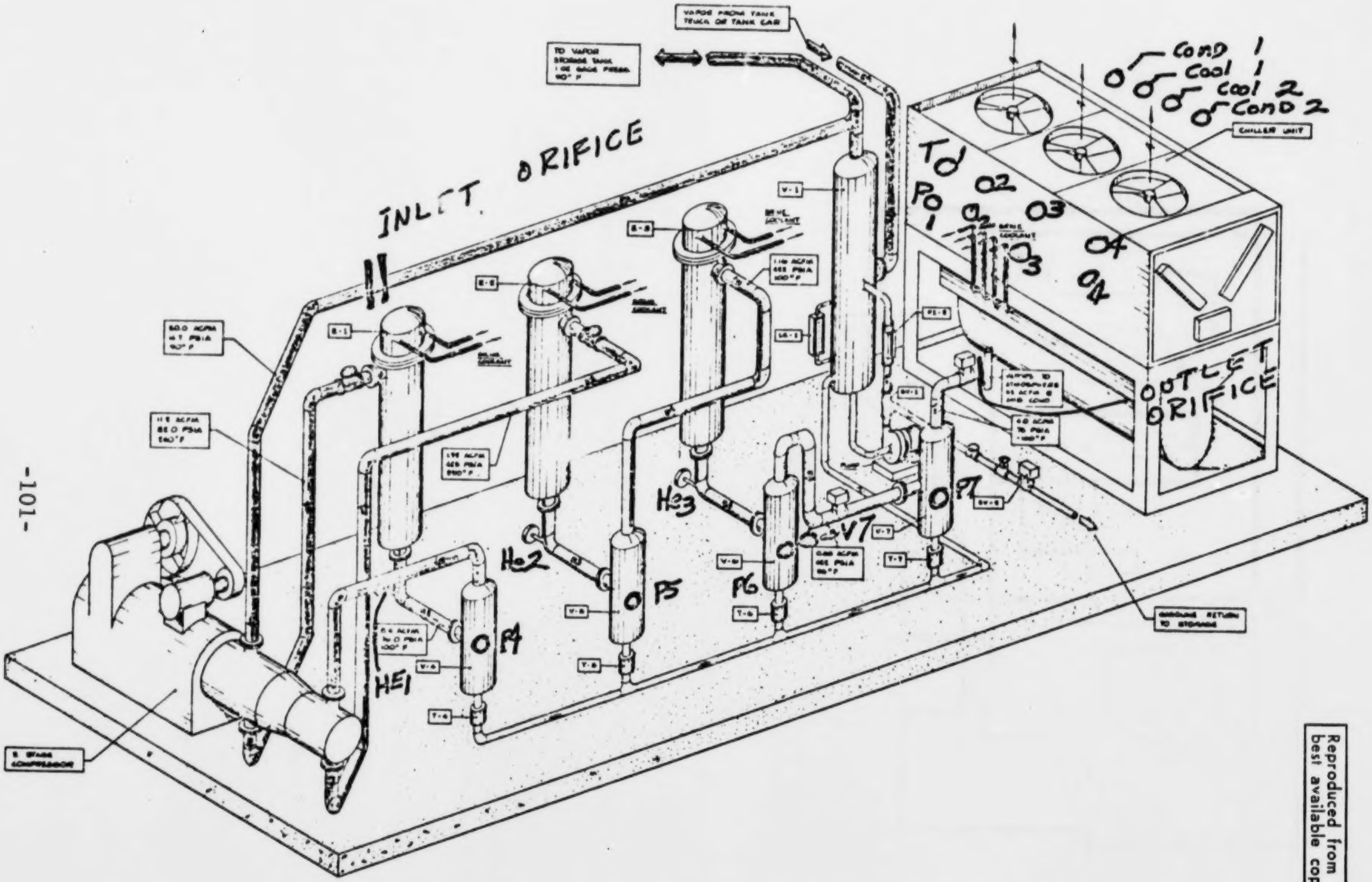

VAPOR FROM TANK TRUCK OR TANK CAR
TO VAPOR STORAGE TANK
INLET ORIFICE
OUTLET ORIFICE
Cond 1
Cool 1
Cool 2
Cond 2
CHILLER UNIT
Td
Po 1
O2
O2
O3
O3
O4
O4
V-1
HE1
He2
He3
P4
P5
P6
P7
V7
V-7
T-7
GASOLINE RETURN TO STORAGE

FIGURE 2.2-15 - COMPRESSION-REFRIGERATION-CONDENSATION UNIT BY GESCO

Reproduced from best available copy.

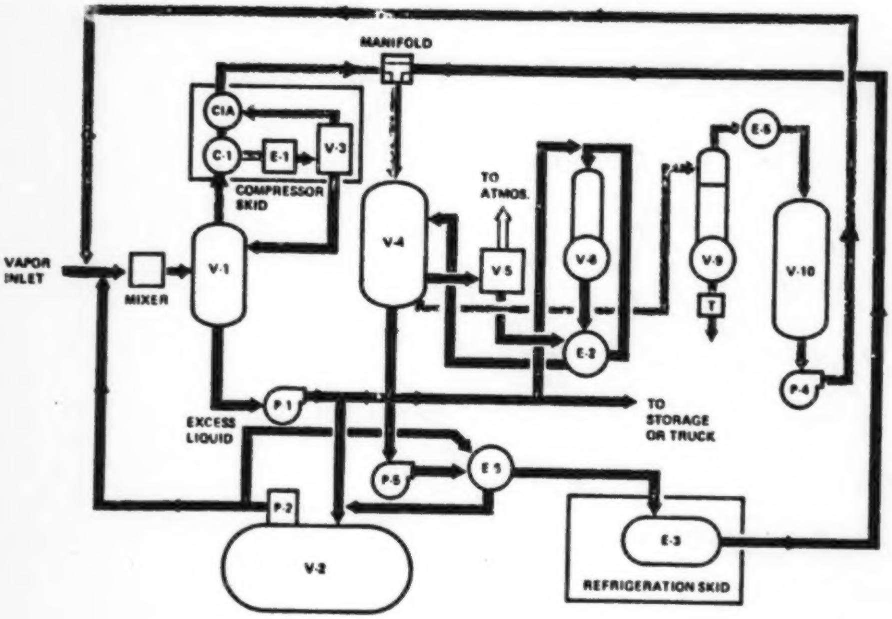

MANIFOLD
C1A
C-1
E-1
V-3
COMPRESSOR SKID
TO ATMOS.
E-6
VAPOR INLET
MIXER
V-1
V-4
V-5
V-6
V-9
T
V-10
E-2
P-1
P-4
EXCESS LIQUID
TO STORAGE OR TRUCK
P-5
E-5
P-2
V-2
E-3
REFRIGERATION SKID

FIGURE 2.2-16 - COMPRESSION-REFRIGERATION-CONDENSATION UNIT BY VAPOREX

V-1	Saturator
V-2	Recovered Product Storage
V-3	Vapor-Liquid Separator
V-4	Condenser
V-5	Vapor-Liquid Separator
V-6	Absorber
V-9	Methanol-Water Fractionator
V-10	Methanol Storage
C-1	First Stage Compression
C1A	Second Stage Compression

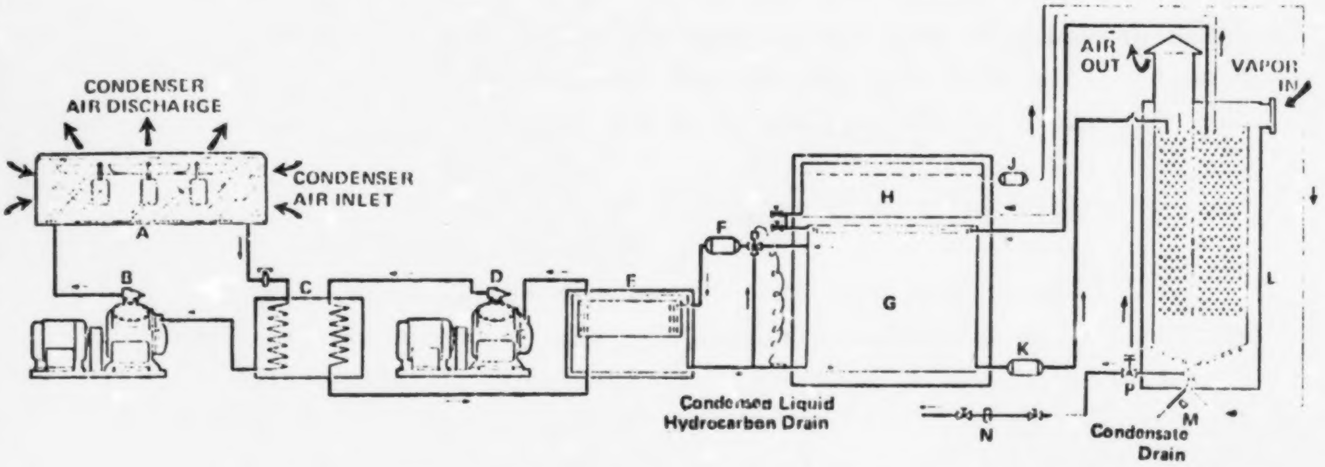
E-1	Interstage Cooler
E-2	Heat Exchanger
E-3	Heat Exchanger
E-5	Heat Exchanger
E-6	Heat Exchanger
P-1	Pump
P-2	Pump
P-4	Pump
P-5	Pump

saturated gasoline vapors and 88% to 90% of the hydrocarbons in subsaturated gasoline vapors from bottom loading operations. Vendors claim that adjustments and optional equipment can improve the efficiency of CRC systems to a minimum recovery of 94%.

Refrigeration Systems

One of the most recently developed vapor recovery systems is the straight refrigeration system, based on the condensation of gasoline vapors by refrigeration at atmospheric pressure. Figure 2.2-17 shows the flow scheme of such a system. Vapors displaced from the terminal enter a horizontal fin-tube condenser where they are cooled to -100° F and condensed. Because vapors are treated on demand, no vapor holder is required. Condensate is withdrawn from the condenser bottom and the remaining air, containing only a small amount of hydrocarbon, is vented from the condenser top. Cooling for the condenser coils is supplied by a methyl chloride reservoir. A two-stage refrigeration unit is used to refrigerate the stored brine solution to between -105° F and 125° F.

The refrigeration vapor recovery unit recommended by the vendor for a 250,000 gpd terminal is capable of handling a vapor rate of 370 CFM. This high capacity is required because of the lack of vapor storage capacity. The FOB cost for this unit is approximately $85,000 and transportation charges run from $500 to $1,500. Utility costs for refrigeration vapor recovery units depends on local utility rates, however, power requirements are 9.4 hp/1000 CF or for the above unit, 320 kwh/day. Overall yearly operating and maintenance rates are reported to be 2% of the capital cost, or $1,600. No estimate was available for installation and site preparation costs but they are in the range of those for CRA and CRC units.


CONDENSER
AIR DISCHARGE
CONDENSER
AIR INLET
A
B
C
D
E
F
G
H
J
K
L
P
M
N
AIR
OUT
VAPOR
IN
Condensed Liquid
Hydrocarbon Drain
Condensate
Drain

A – AIR-COOLED CONDENSER, HIGH STAGE
B – HIGH STAGE COMPRESSOR
C – HIGH TEMPERATURE EVAPORATOR and LOW TEMPERATURE CONDENSER
D – LOW STAGE COMPRESSOR
E – LOW TEMPERATURE EVAPORATOR
F – BRINE PUMP
G – COLD BRINE STORAGE RESERVOIR
H – DEFROST BRINE and EXPANSION CHAMBER
J – DEFROST PUMP
K – COOLANT PUMP
L – VAPOR CONDENSER
M – ELECTRIC WATER CONTROL VALVE
N – POSITIVE DISPLACEMENT METERING PUMP FOR CONDENSED HYDROCARBONS
P – FLOAT VALVE

FIGURE 2.2-17 - REFRIGERATION VAPOR RECOVERY UNIT BY EDWARDS

The vapor recovery efficiency of refrigeration systems is again dependent on the hydrocarbon concentration of the inlet vapors. Field tests of a unit with a condenser temperature of -100° F indicate the outlet hydrocarbon concentration is relatively fixed by the condenser temperature at 0.6% to 2.6% by volume. Typical hydrocarbon recoveries are 93% to 97% with recoveries reaching 99% for saturated inlet vapors.

Lean Oil Absorption Systems

The lean oil absorption (LOA) vapor recovery system is based on the absorption of gasoline vapors into lean gasoline stripped of light ends. Figure 2.2-18 is a flow scheme of a LOA vapor recovery system. Gasoline vapors from the terminal are displaced through the packed absorber column where they are absorbed by cascading lean gasoline (termed sponge oil or lean air) at atmospheric temperature and pressure. Stripped air is vented from the top of the absorber column. The enriched gasoline is returned to storage. Lean gasoline for the absorber is generated by heating gasoline from the storage tanks and evaporating off the light ends. The separated light ends are compressed, condensed, and returned to storage, and the lean gasoline is stored separately for use in the absorption column.

Cost figures were not available for LOA vapor recovery systems.

The vapor recovery efficiency of LOA systems is dependent on the liquid to vapor ratio in the absorber and on the hydrocarbon content of the inlet vapors. The manufacturer reports that normal practice is to adjust the lean oil feed rate to the absorber such that the hydrocarbon content of the stripped

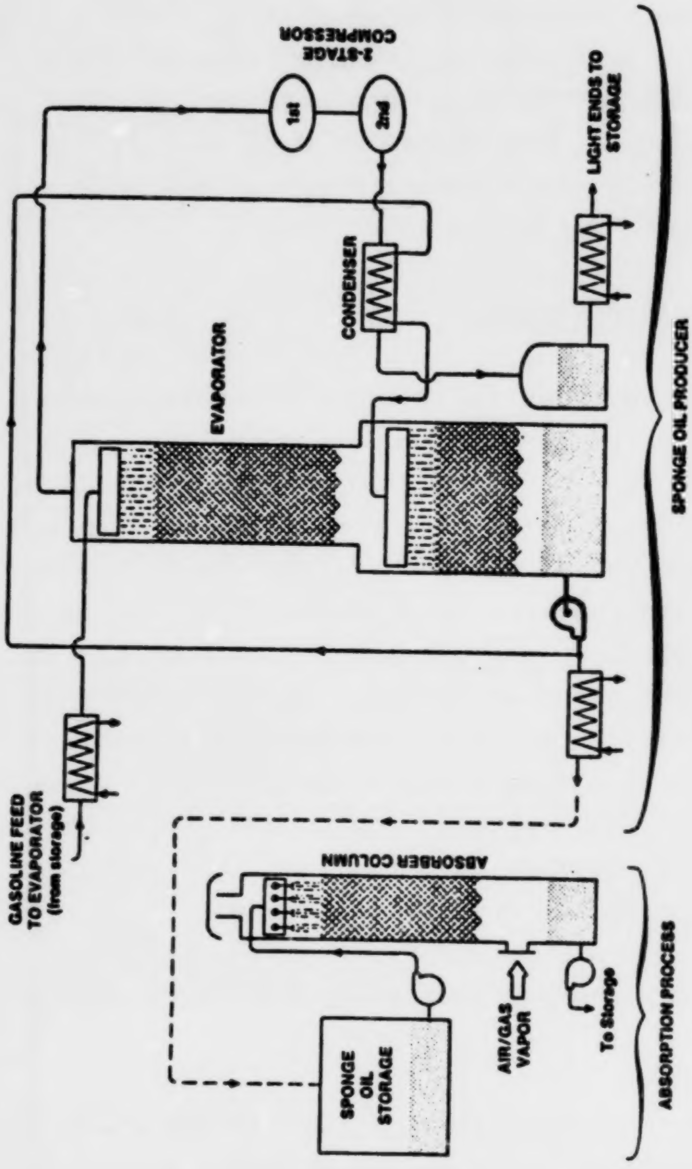

GASOLINE FEED
TO EVAPORATOR
(from storage)
EVAPORATOR
CONDENSER
1st
2nd
2-STAGE
COMPRESSOR
LIGHT ENDS TO
STORAGE
SPONGE OIL PRODUCER
ABSORBER COLUMN
SPONGE
OIL
STORAGE
AIR/GAS
VAPOR
To Storage
ABSORPTION PROCESS

FIGURE 2.2-18 - LEAN OIL ABSORPTION SYSTEM BY SOUTHWEST INDUSTRIES

air is 3% by volume. This corresponds to a 90% or greater recovery for inlet hydrocarbon concentrations of 24% or greater. Higher lean oil rates are used when improved recovery is required.

Flame Oxidation Systems

One of the simplest vapor control systems for bulk terminals is the flame oxidation system. This system controls hydrocarbon emissions by combusting gasoline vapors as opposed to recovering them as a liquid product. Figure 2.2-19 is a flow scheme of a typical flame oxidation unit. Gasoline vapors from the terminal are displaced to a vapor holder as they are generated. A hydrocarbon analyzer system adds propane to the vapor holder when necessary to maintain the hydrocarbon/air ratio above its flamability limit. When the vapor holder reaches its capacity the gasoline vapors are released to the oxidizer, after mixing with a properly metered air stream and combusted to a carbon dioxide and water.

Although depending on terminal operating schedules and vapor storage capacity it was assumed that a 250,000 gpd bulk terminal would require a 150 CFM flame oxidation unit. The FOB cost of such a unit is $50,000. Costs for vapor holders for this size unit range from $8,000 to $20,000 FOB. Although site preparation and installation costs were not available, they are expected to be lower than those for other types of vapor recovery units because no recovered product tanks and recovered product lines are needed. Utility costs are low because no compressors or refrigerators are involved, however, there is an undetermined propane fuel cost incurred. The simplicity and low capital cost of flame oxidation units is largely offset by the economic loss by combusting the valuable gasoline product.

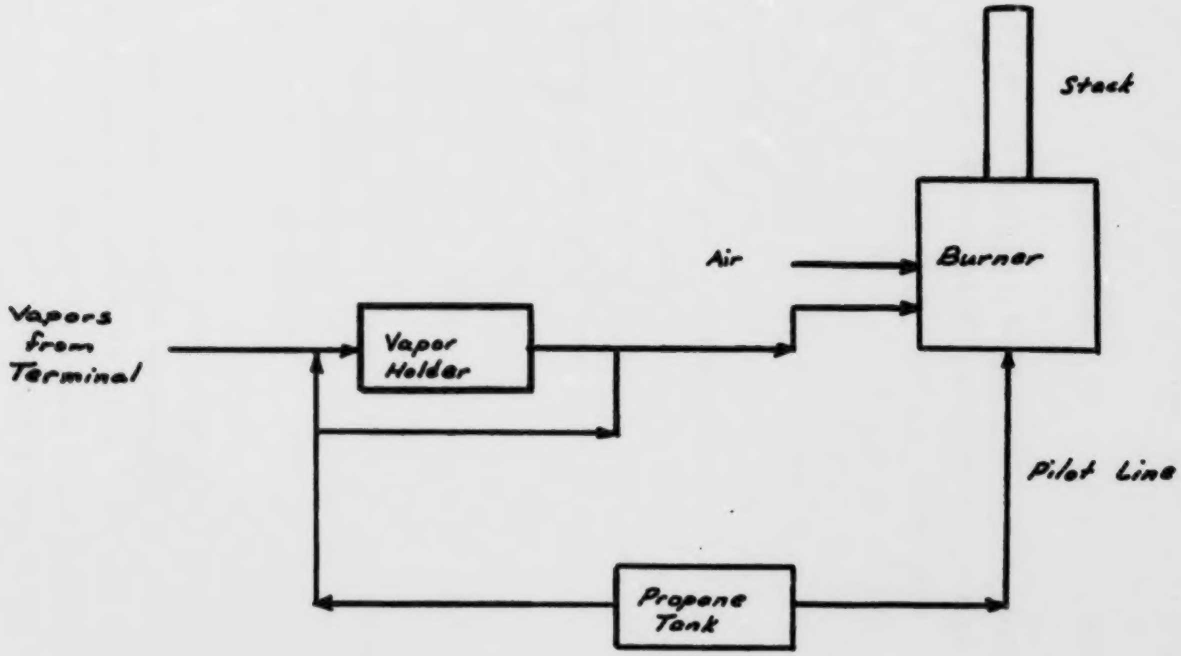

Stack
Air
Burner
Vapors from Terminal
Vapor Holder
Pilot Line
Propane Tank

FIGURE 2.2-19. FLAME OXIDATION SYSTEM BY AER CORPORATION

2.2.1.3 Vapor Recovery Units (Cont.)

Properly designed and operated flame oxidation units usually achieve hydrocarbon removal efficiencies of about 99% (VO-037). Test results on the efficiency of a flame oxidation unit designed for bulk terminal use indicated hydrocarbon concentrations in the stack gas to be less than 55 ppm. This corresponds to 99+% disposal of hydrocarbon vapors.

Operating Reliability

The operating reliability of terminal vapor recovery systems is generally good. The technology is proven through use by industry over two decades. Companies using CRA and CRC units report average downtime for properly maintained units is about one week per year. Freezing problems have occurred with CRA, CRC, and refrigeration systems where the vapors are subject to temperatures below 32° F. Water vapor contained in the air freezes in the system, hindering heat transfer and clogging lines. The two solutions to this problem have been:

(1) include n automatic defrost cycle which shuts down part of the system during off-periods and allows for defrosting the iced sections, and

(2) inject methanol into the system to lower the freezing point of the aqueous layer.

Both solutions to the icing problems generally work well, however, isolated problems with icing still occur.

Another major source of problems in CRA and CRC systems is the gasoline vapor compressor. Compressors handling heterogeneous mixtures of air, light hydrocarbons, and water vapor have maintenance problems in rotors and bearings normally encountered with closed loop refrigerant compressors. There have also been reports that some lean oil absorption units are experiencing problems in obtaining adequately stripped lean oil feed to the absorber.

Safety

Safety is always of paramount importance in designing equipment to handle flamable materials. The manufacturers of vapor recovery equipment have been conscious of this, and have included safety features in their designs. Flame oxidation, CRC, and CRA units have potential safety problems whenever explosive hydrocarbon mixtures are being stored and processed. To eliminate the possibility of explosion, these units are generally equipped with means to saturate the incoming vapor stream which raises the hydrocarbon content above the explosive range. Refrigeration systems generally operate at temperatures below which explosions are a threat.

CRA and CRC systems have the problem of compressing hydrocarbon vapors. The adiabatic heat of compression increases the outlet gas temperature to the point where it is much more easily ignited than is the cooler inlet vapors. Compression ratios and the corresponding outlet gas temperatures must be maintained at levels low enough to prevent excessive heating and spontaneous combustion.

Another potential safety problem in systems employing vapor holders has been leakage creating explosive mixtures in the air space above the diaphragm. Regularly maintained and inspected diaphragms should pose no safety problems.

2.2.1.3 Vapor Recovery Units (Cont.)

Because these are largely custom made, none of the vapor recovery systems currently have obtained Underwriters Laboratory approval. The majority of the systems, however, do conform to Class I, Group D, Division 1 of the National Electric Codes and in addition comply with all other applicable engineering codes and standards.

Manufacturing Capacity

The manufacturing capacity and installation time of the vapor recovery industry is dependent on the availability of supplies, equipment, contractors, labor, and weather. Recent estimates by the top eight manufacturers are that their yearly production rate is four to five hundred units although this rate could be expanded if the need arises. CRA and CRC manufacturers have a nine to twelve month delivery time, while manufacturers of refrigeration, LOA, and flame oxidation units report six month delivery times. These manufacturing capacities and delivery times may be optimistic in light of the current economic situation and material shortages.

Summary

The five major types of vapor recovery systems for terminals are compression-refrigeration-absorption, compression-refrigeration-condensation, straight refrigeration, lean oil absorpiton, and flame oxidation. The technology of each system is well developed. Each of these vapor recovery systems are capable of meeting 90% recovery although some may require adjustments or additional equipment to meet 90% recovery on inlet streams having a very low hydrocarbon concentration. The reliability of vapor recovery units for bulk terminals is good and is continuously being improved. Future stream factors, assuming proper maintenance should be in the 95% category.

Manufacturers of vapor recovery units have been cognizant of the importance of safety and have generally conformed to applicable engineering codes and standards. Care has been taken to prevent ignition sources and to maintain the vapors in non-explosive regimes.

The current manufacturing capacity of the vapor recovery industry is four to five hundred units per year with a delivery time of six months for refrigeration, LOA, and flame oxidation units and nine to twelve months for CRA and CRC units.

Table 2.2-3 summarizes the information presented in this section on vapor recovery units. Greater cost breakdowns are presented in Section 3.5. Seasonal and inlet concentration effects on the efficiency of vapor recovery units are discussed in Section 3.8.

Computer Simulation

A computer modeling study was undertaken to predict the recovery efficiencies and emission concentrations of three types of vapor recovery systems. The operating conditions of each of the systems used for this study are listed below.

System	Operating Temperature	Operating Pressure
Refrigeration	-100° F	15 psia (Ambient)
CRA	0	65 psia
CRC	25° F	440 psia

Two vapor concentrations were used to predict the effects resulting from an increase in hydrocarbon concentration of the vapors processed by a particular unit. Hydrocarbon

TABLE 2.2-3

CHARACTERISTICS OF VAPOR RECOVERY UNITS FOR BULK TERMINALS

Vapor Recovery System	Unit Cost FOB	Operating and Maintenance Cost	Site Preparation and Installation Cost	Power Requirements (kwh/day)	Vapor Recovery Efficiency	Yearly Manufacturing Capacity	Delivery Time (months)	Operating Temperature °F	Operating Pressure (psig)	Unit Outlet Concentrations[1]	
										(Percent hydrocarbon)	(gm/gallon transferred)
CRA	$83,000-$90,000	$1,660-$2,700	$25,000-$80,000	250-360	90%-97%	288	9-10	-10° to amb.	45-210	4.3-4.7	0.13
CRC	$80,000-$100,000	$2,000-$3,000	$5,000-$25,000	370	90%-96%	62	8-12	-10° to 30°	85-410	-------	----
Refrigeration	$80,000	$1,600	-	320	93%-99%	52	6	-100°F	atm.	2.0-4.0[2]	0.13-0.15[2]
LOA	-	-	-	-	90%-95%	60	6	amb.	atm.	-------	----
Flame Oxidation	$50,000	-	-	-	98%-99%	30	4	-	atm.	<1.0	----

---

1. Based on source test data.

2. Unit not at optimum conditions during test.

concentrations chosen for this study were 15% and 40%. The component breakdown of the vapors used for each composition were as follows.

Component	Hydrocarbon Concentration 15% HC	 40% HC
Air	85.0%	60.0%
C_4	7.5%	20.0%
C_5	4.9%	13.2%
C_6	1.7%	4.4%
C_7	0.9%	2.4%

The results of this study are summarized in Table 2.2-4. As is illustrated in this table, the outlet concentration of the vapors from a vapor recovery unit are relatively fixed by equilibrium conditions of the unit's operating temperature and pressure. An increase of the hydrocarbon concentration of vapors going to the unit will result in an increase in the unit's recovery efficiency but will have little effect on the hydrocarbon concentration in the vapors from the vapor recovery unit. The mass emissions will, however, decrease as the inlet hydrocarbon concentration increases. This is because the amount of air being passed through the unit decreases while the hydrocarbon concentration in the outlet vapors remains constant.

2.2.2 Service Stations

The main sources of hydrocarbon emissions from service stations are the underground tank refilling and vehicle refueling operations. There is considerable experience with emission controls for both sources. Emission control of underground

TABLE 2.2-4

SUMMARY OF COMPUTER CALCULATIONS

System Type	Inlet Hydrocarbon Concentration (%)	Outlet HC Concentration (%)	% Recovery[1]	Mass Emissions[2] (gm)
Refrigeration	15	0.9	94.0	541
	40	0.9	98.0	381
CRC	15	2.5	83.0	1553
	40	2.6	93.5	1092
CRA	15	2.5	83.0	1634
	40	2.5	94.0	1126

---

[1] Based on Volume % Recovery

[2] Assuming 1000 ft^3 of Inlet Vapor at 70° F

tank filling operations has been designated as Stage I controls and control of vehicle refueling operations has been designated as Stage II controls. Emission control technology, for both stages of control, will be discussed in this section.

2.2.2.1 Stage I Control Technology

Substantial test data exists which indicate that 95% of the vapors displaced from underground tank refilling can be recovered by simply returning the displaced vapors to the tank truck. Examples of this data are shown on Tables 2.2-5, 2.2-6, and 2.2-7 (ST-187, HA-256, SC-186). These data indicate that a well-designed vapor balance system will provide efficient control of underground tank refilling vapors with the use of emission control technology and equipment available today.

The following discussion will be directed toward several important parameters which affect the efficiency of recovering vapors from underground tank refilling.

Submerged Fill Pipe

A submerged fill pipe is used in order to discharge a load of gasoline below the surface of liquid in the underground tank. Submerged loading eliminates the excess vapors which would be generated from discharging the gasoline at the top of the tank as the free fall of the gasoline droplets would promote evaporation and could result in liquid entrainment of some gasoline droplets in the expelled vapors.

Tank Vapor Fittings

There are two basic approaches to collecting displaced vapors from underground tank refillings: single and dual point

TABLE 2.2-5

DATA AND RESULTS OF DISPLACEMENT VAPOR RECOVERY STUDY FOR UNDERGROUND DELIVERIES

Test No.	Date	Product Unloaded		Temperature, °F		Pressures in System, In. H_2O		Product Flow Rate, Gal./Min.	Excess Vapor, Ft^3	Vapor Recovery, %
		Volume, Ft^3	Temperature, °F	Underground Product	Ambient	Underground Tank	Truck			
1	6-7-73	213.9	80	80	82	0.76	-0.07	397	12.4	94.5
2[1]	6-7-73	213.9	82	80	86	0.57	-0.74	390	16.4	92.9
3[1]	6-7-73	213.9	81	81	89	0.29	-0.98	392	18.0	92.2
4[2]	6-12-73	254.0	71	77	80	0.07	-0.78	416	12.5	95.3
5[2]	6-12-73	254.0	78	74	88	0.25	-0.47	421	14.3	94.5
6[2]	6-13-73	254.0	75	78	70	0.20	-0.51	430	8.6	96.7
7[2]	6-13-73	213.9	89[3]	77	76	0.24	-0.36	386	17.0	92.6
8	6-14-73	213.9	81	81	65	0.20	-0.63	387	5.1	97.7
9	6-14-73	213.9	81	81	68	0.23	-0.62	386	5.8	97.4
10	6-14-73	588.2	80	80	69	0.26	-0.74	493	20.4	96.6
11	6-14-73	588.2	80	80	69	0.33	-0.77	494	21.7	96.4
12	6-14-73	213.9	80	80	74	0.28	-0.60	400	11.7	94.8
13	6-14-73	213.9	80	80	78	0.25	-0.63	397	14.5	93.7
14	7-10-73	554.8	77	78	80	0.27	-1.05	430	0.0	100.0
15	7-10-73	581.6	76		84	0.39	-1.30	494	0.0	100.0
16	7-10-73	558.8	84	84	100	0.39	-0.60	477	41.6	93.1
17	7-31-73	254.0	82	82	97	0.05	-0.55	403	2.4	99.1
18	8-29-73	581.6	82	82	94	0.40	-1.48	493	42.9	93.1
Average		343	80	75	80	0.30	-0.72	427	14.7	95.6

---

[1] Dry break adapter on vapor return line.

[2] Test performed with Scott Research Laboratories for API EF-14 Project.

[3] Artificially heated.

	Diameter, In.	Length, Ft
Vapor Return Hose	3	18
Delivery Hose	4	18

TABLE 2.2-6

SUMMARY OF BULK DROP DATA

Secondary	Drop (gal)	Volume (ft^3)	Vented (ft^3)	Volume Efficiency (%)	Mass Emission (gm)	Unit Mass (gm/gal)	Fuel Pressure (in.H_2O)
Environics	7800	1043	10.14	99+	14.45	.002	0
Intermark	8685	1161	6	99+	28.5	.003	2.5
Process Products	8800	1180	0*	100	0	0	1.5
Balanced							
Gulf	8250	1103	26.3	97.6	260	.03	0
Standard	4565 **	623.7	23.8	95.2	183	.04	0

* The underground piping at this station had a leak which was subsequently discovered. Venting may occur after the leak is repaired.

** Standard Balanced represents a normal drop of approximately 4000 gallons into each underground tank. Only the tested tank is indicated because the Standard Station uses separate vapor line for each grade of product. Other stations use a manifold connecting the underground tanks.

By: EPA-TRW From: Test Evaluation of Gasoline Transfer Vapor Recovery Systems, August 1974.

TABLE 2.2-7

SUMMARY OF VAPOR EMISSIONS - TANK TRUCK DELIVERY TESTS WITH SERVICE STATION VAPOR CONTROL SYSTEMS

Participant	Total No. of Tests	Recovery Concept	Average % Emission(1)	Average % Emission(4)
Arco	4	Activated Carbon	0.00(2)	0.00(2)
Union	6	Refrigerated-Condensation	0.00	0.00
Arco	8	Direct Displacement	5.81	4.06
Amoco	11	Direct Displacement	4.12	4.12
Exxon	8	Direct Displacement	7.75	3.61
Citgo	8	Direct Displacement	2.40	2.40
Sun	17	Direct Displacement	6.86	2.38
Mobil	19	Direct Displacement	4.49	3.68
Shell	8	Direct Displacement	5.86	5.86
Std-Cal	8	Direct Displacement	2.11	2.11
		Average	5.04%(3)	3.51%(3)

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(1) % loss by volume unless otherwise noted; all tests.

(2) % volume losses approximately same as typical Direct Displacement values; however, HC concentration < 1/1000 of D.D. emission.

(3) Average of Direct Displacement tests, weighting each test equally.

(4) Excluding atypical tests.

systems. The dual systems employ two tank fittings; one for product delivery and one for vapor collection. The single point systems employ only one fitting; a coaxial or concentric fuel-vapor coupler. See Figure 2.2.-20 for a diagram of a coaxial fitting.

The advantage of the coaxial-type fitting is that an interlock system can be built in which will prohibit product delivery unless the vapor return line is connected. A disadvantage of the coaxial coupler is that it will result in lower product delivery rates than could be achieved with a standard four-inch drop tube as the space required for vapor collection creates a flow restriction in the gasoline entry line.

Vent Pipe Restrictions

The use of vent pipe restrictions have been suggested as a means of encouraging drivers to hook up the vapor return hose in a dual point system. If the vapor return line is not hooked up, the vent pipe restriction will create a back pressure in the underground tank and hence impede the rate of product delivery. It has been suggested that a restriction should double the time required for a truck drop to be effective.

Calculations have been performed to determine the effect on drop rate of different sized orifices. A one-half inch vent pipe orifice will result in a drop delay of 47%, while a three-eighth inch orifice will delay the drop time by 66%. The smaller orifice, however, places more stress on the tank, plus it takes the system longer to vent down to a safe level before the product delivery hose can be disconnected.

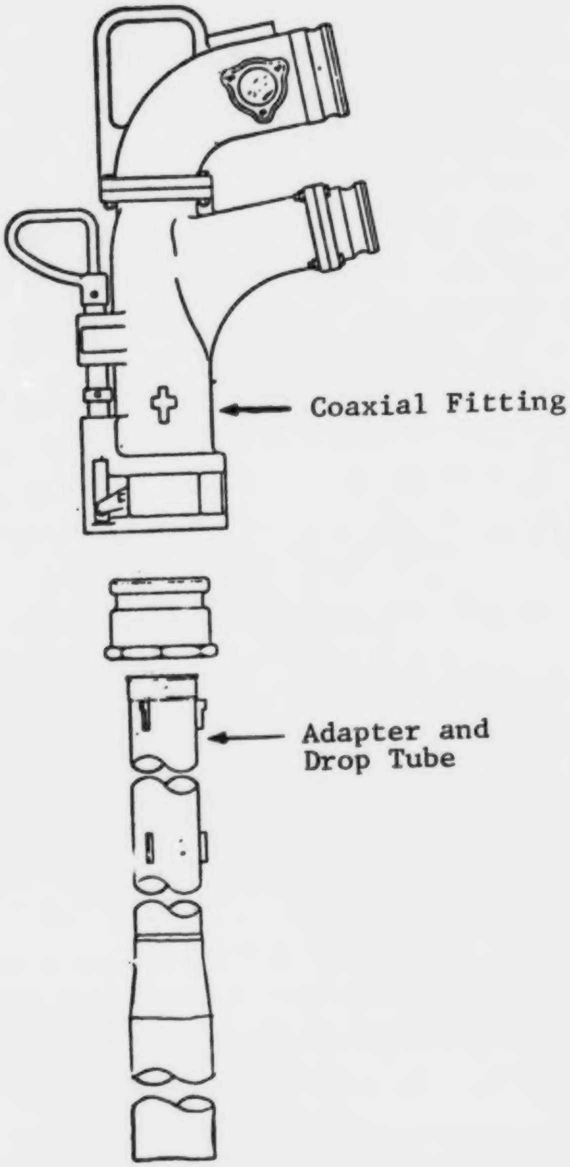

Coaxial Fitting
Adapter and Drop Tube

FIGURE 2.2-20. DIAGRAM OF A COAXIAL FITTING AND FILL TUBE ADAPTER

Safety Considerations

Creation of pressure in the underground tank is the main safety problem associated with recovering displaced vapors from refilling operations. Relatively low pressures can be created by the use of a pressure-vacuum valve or a restrictive orifice in the tank vent line under normal operations. However, if the orifices become plugged or the P-V valve becomes stuck, high pressures can result.

The effects of pressure in the underground tank can be catastrophic. In most instances, however, it will probably result in poor operation of the vapor recovery system. Some of these pressure effects are listed below.

(1) Rupture of the underground tank,

(2) Transfer through the vapor return line to a vehicle tank which can result in gasoline spitback, but will definitely prohibit the transfer of vapors to the underground tank.

(3) Gasoline can be forced out of the gasoline delivery hose if a system containing a restrictive orifice is not vented down before the hose is disconnected.

Routine inspections of all vapor recovery equipment, especially pressure-vacuum valves and restrictive orifices, should be performed to insure proper operations. The frequency of inspections should be increased during freezing and icy weather. At these conditions a pressure-vacuum valve or orifice is most likely to freeze up.

Truck Inspections

Truck inspections are a necessary and integral part of any vapor recovery program. The inspections should be designed to detect any leaks in the truck vapor compartments through periodic pressure checks in each truck. Leaks in the truck will permit collected gasoline vapors to escape to the atmosphere and thus greatly reduce the recovery efficiency.

Design Criteria

The following specifications have been recommended by EPA to aid in the design and installation of a system to recover vapors resulting from underground tank refilling operations.

(1) Drop Tube Specifications

Submerged fill is specifically required by certain TCP regulations while others are silent on the method of filling. All test data submitted to EPA were obtained from systems utilizing submerged fill. If submerged fill is not used, test data must be submitted to show the required recovery will be obtained. The submerged fill requirement is interpreted to mean a drop tube extending to within 6 inches of the tank bottom. Under normal industry practices, a tube meeting this specification will always be submerged since the tanks are not pumped dry.

Deviation from the criteria will be allowed if the owner/operator shows that a shorter tube will guarantee submerged fill. In such instance, the owner/operator is required to present records which show that the level in the tank never falls below the drop tube. Exceptions also will be allowed for tanks which cannot be converted to submerged fill, e.g., tanks with offset fill lines or poor accessibility.

(2) Gauge Well

If a gauge well separate from the fill tube is used, it must be provided with a drop tube which extends to within 6 inches of the tank bottom. This will prevent vapor emissions in case the gauge well cap is not replaced during a drop.

(3) Vapor Hose Return

Existing data indicate that a 3-inch ID hose is needed to transfer vapors from the storage tank to the truck. Smaller diameter hoses may be satisfactory where fill rates are appreciably less than 400 gallons per minute. If a hose smaller than 3 inches is to be used, the owner/operator is required to show that the hose will achieve the required vapor recovery.

(4) Size of Vapor Line Connections

Where separate vapor lines are used with 4-inch product tubes, nominal 3-inch or larger connections should be utilized at the storage tank and truck-trailer. When smaller product tubes are used, a smaller vapor line connection may be used, provided the ratio of the cross-sectional area of the connection to the cross-sectional area of the product tube is 1:2 or greater. If the ratio is smaller, test data must be provided to show the required recovery efficiency will be met.

For concentric or other tube-in-tube fittings, operating characteristics are unique to the particular design. To date, adequate test data have been supplied for 4-inch and 6-inch tube-in-tube adapters.

2.2.2.1 Stage I Control Technology (cont.)

(5) Type of Liquid Fill Connection

Vapor tight caps are required for the liquid fill connection for all systems. A positive closure utilizing a gasket or other similar sealing surface is necessary to prevent vapors from being emitted at ground level. Cam-lock closures meet this requirement. Dry-break closures also are acceptable, but are not required.

(6) Tank Truck Inspection

Vapor tight tank trucks are specifically required by TCP regulations. This is interpreted to mean that the truck compartments won't vent gases or draw in air unless the settings of the pressure-vacuum relief valves are exceeded. An inspection procedure should be submitted to include frequent visual inspection and leak testing at least twice per year. Leak testing should demonstrate that the tank truck when pressurized to 5 inches W.C. will not leak to a pressure of 2 inches W.C. in less than 3 minutes. Frequent visual inspection is necessary to insure proper operation of manifolding and relief valves.

(7) Closures or Interlocks on Underground Tank Vapor Riser

Closures or interlocks are required to assure transfer of displaced vapors to the truck and to prevent ground level gasoline vapor emissions due to failure to connect the vapor return line to the underground tanks. These devices must be designed:

(a) to keep the storage tank sealed unless the vapor hose is connected to it; or

(b) to prevent delivery of fuel until the vapor hose is connected, i.e., an interlock.

Concentric couplers are required to have acceptable closures on the vapor line connection in the coupler itself rather than on the riser pipe from the storage tank.

(8) Vapor Hose Connection to the Tank Truck

A means must be provided to assure that the vapor hose is connected to the truck before fuel is delivered. Acceptable means of providing this assurance include:

(a) permanent connection of the vapor hose to the truck;

(b) an interlock which prevents fuel delivery unless the vapor hose is connected, such as a bracket to which the product and vapor hose are permanently attached so that neither hose can be connected separately; and

(c) a closure in the vapor hose which remains closed unless the hose is attached to the vapor fitting on the truck.

(9) Vent Line Restrictions

Vent line restrictions improve recovery efficiency and provide assurance that the vapor return line will be connected during transfer. If the liquid fill line were attached to the underground tank and the vapor return line disconnected, closures would seal the vapor return path to the truck forcing all vapors out the vent line. Restriction of the vent line through the use of an orifice or pressure-relief valve greatly reduces fill rate in such instances warning the operator that the vapor line is not connected.

Where concentric or tube-in-tube connections are utilized, a restriction should be installed in the underground tank vent pipe. These connectors provide considerably less cross-section area in the vapor return passage than do 3-inch connectors. Hence, a restriction in the vent pipe is required to insure that the required emission limit will always be met. If systems utilizing tube-in-tube connections are to be installed without vent pipe restrictions, testing data will be required to show that the emission limit is being met.

Suitable restrictive orifices or pressure-relief valves are required whenever the systems would otherwise be incapable of achieving 90% control or would otherwise not assure that the vapor return line is connected. For available hardware this means that these restrictive devices are necessary for all except systems with interlock connections at both the truck and storage tank.

Either of the following restrictive devices are acceptable:

(a) Orifice of 1/2 to 3/4 inch ID.

(b) Pressure-vacuum relief valve set to open at 8 oz per square inch or greater pressure and 4 oz per square inch or greater vacuum. The vacuum relief feature of a P-V valve is not required for Stage I recovery purposes but may be required by safety authorities.

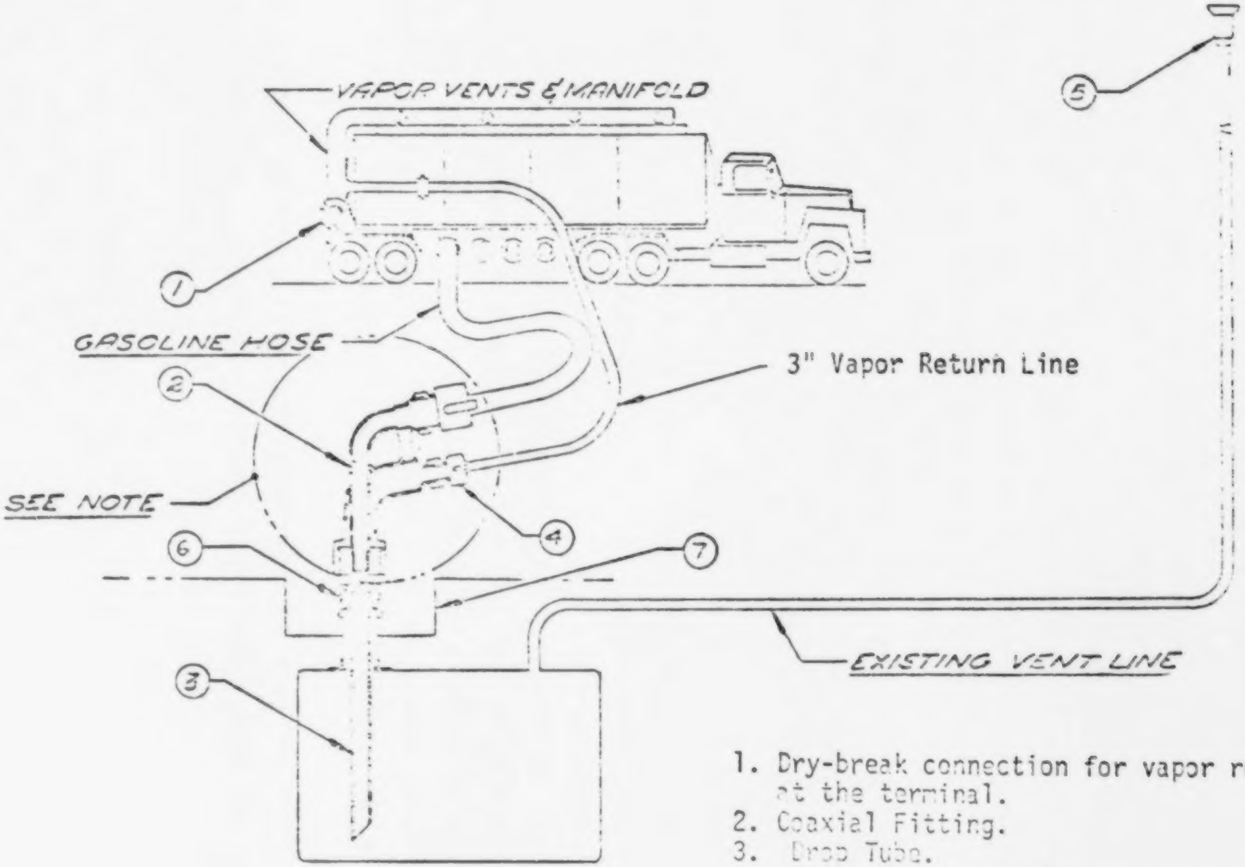
Figure 2.2-21 shows a schematic sketch of a well-designed vapor displacement system for recovery of underground storage tank vapors. The system depicted employs a concentric or coaxial vapor-liquid connector.

2.2.2.2 Stage II Control Technology

Stage II controls refer to control during vehicle refueling. It is in this area where much disagreement remains on the effectiveness of different means of emission control. Most of the controversy centers on the relative advantages/disadvantages of two basic types of emission control systems: vapor displacement and vacuum assist.

The vapor displacement, or vapor balance system operates by simply transferring vapors to the underground tank where they are stored until final transfer to a tank truck. Pressure created in the vehicle tank and vacuum created in the underground tank are the principal agents of vapor transfer. The main pieces of equipment associated with a vapor balance system are a specially designed nozzle which is designed to form a vapor tight seal at the fill neck interface, a flexible hose, and an underground piping system to transport the vapors to the underground storage tank. The underground storage tank vent line can either be open to the atmosphere or equipped with a P-V valve to aid in retaining a vacuum in the underground tank.

FIGURE 2.2-21. COAXIAL VAPOR RECOVERY SYSTEM


VAPOR VENTS & MANIFOLD
①
GASOLINE HOSE
②
SEE NOTE
⑥
③
④
⑦
⑤
3" Vapor Return Line
EXISTING VENT LINE
NOTE:
COAXIAL FITTING
DRAWN OVERSIZE

1. Dry-break connection for vapor return connection at the terminal.
2. Coaxial Fitting.
3. Drop Tube.
4. Dry-break connection on vapor return line.
5. PV valve or orifice on underground tank vent.
6. Coaxial fill adaptor on underground tank 4" riser
7. Manhole.

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Retaining a slight vacuum (2-4" H_2O) in the underground aids the operation of a displacement system in two manners. First of all, it reduces the pressure drop through the vapor piping system which aids the flow of vapors to the underground tank and it also eliminates outbreathing.

Designs of commercially available vacuum assist systems vary widely. All do, however, employ a blower or vacuum pump and a secondary recovery device. The vacuum pump creates a negative pressure in the vehicle fill neck which "pulls" hydrocarbon vapors either directly to the secondary unit or to the underground tank with the excess vapors going to a secondary unit. The amount of vapor collected by this type system is greater than the amount that would be displaced by the balance system filling operations. The additional air ingested causes the evaporation of additional hydrocarbons.

The main processing operations employed by secondary control devices are compression, refrigeration, absorption, and oxidation. One secondary control device may use one or several of these operations to achieve the necessary control. The equipment associated with these type systems is generally complex, expensive, and subject to mechanical failure. Equipment associated with a balance system on the other hand is simple, less expensive, contains no moving parts (except for the nozzle) and is thus not subject to operational downtimes.

This section of the document will provide technical assessments of each type vapor recovery system.

(1) Vapor Balance or Displacement

Description of System

The major components of a vapor balance system are a vapor recovery nozzle, a flexible hose, and underground piping. The function of the vapor recovery nozzle is to effect a leak-free seal at the fill pipe interface. When the seal is made, vapors displaced from the vehicle tank will flow through a vapor passage in the nozzle, but may also escape collection through vents or leaks in the vehicle tank.

The function of the flexible hose is to provide a means of transferring the displaced vapors from the nozzle to the underground pipe. The hose is connected to the outlet of the nozzle vapor passage and to the inlet of the underground pipe which provides a path of vapor flow to the underground tank. Experience with these systems has indicated that a flexible hose size of at least 3/4" and an underground pipe size of at least 2" are necessary to prevent excessive system pressure drops. Furthermore, experience has shown that a slope of 1/8 to 1/4 " per foot will provide a sufficient gradient for any condensed vapors to flow to the underground tank. Figure 2.2-22 shows a diagram of a vapor balance system with manifolded vent lines.

The major differences in vapor balance systems are found in designs of nozzle, piping configurations, and underground tank vent line controls. Some systems return the displaced vapors to individual tanks while others manifold them together. Pressure-vacuum valves can be used to control breathing of the underground tank. In addition, they have the capability of taking advantage of the vacuum developed in the underground tank upon vehicle refueling.

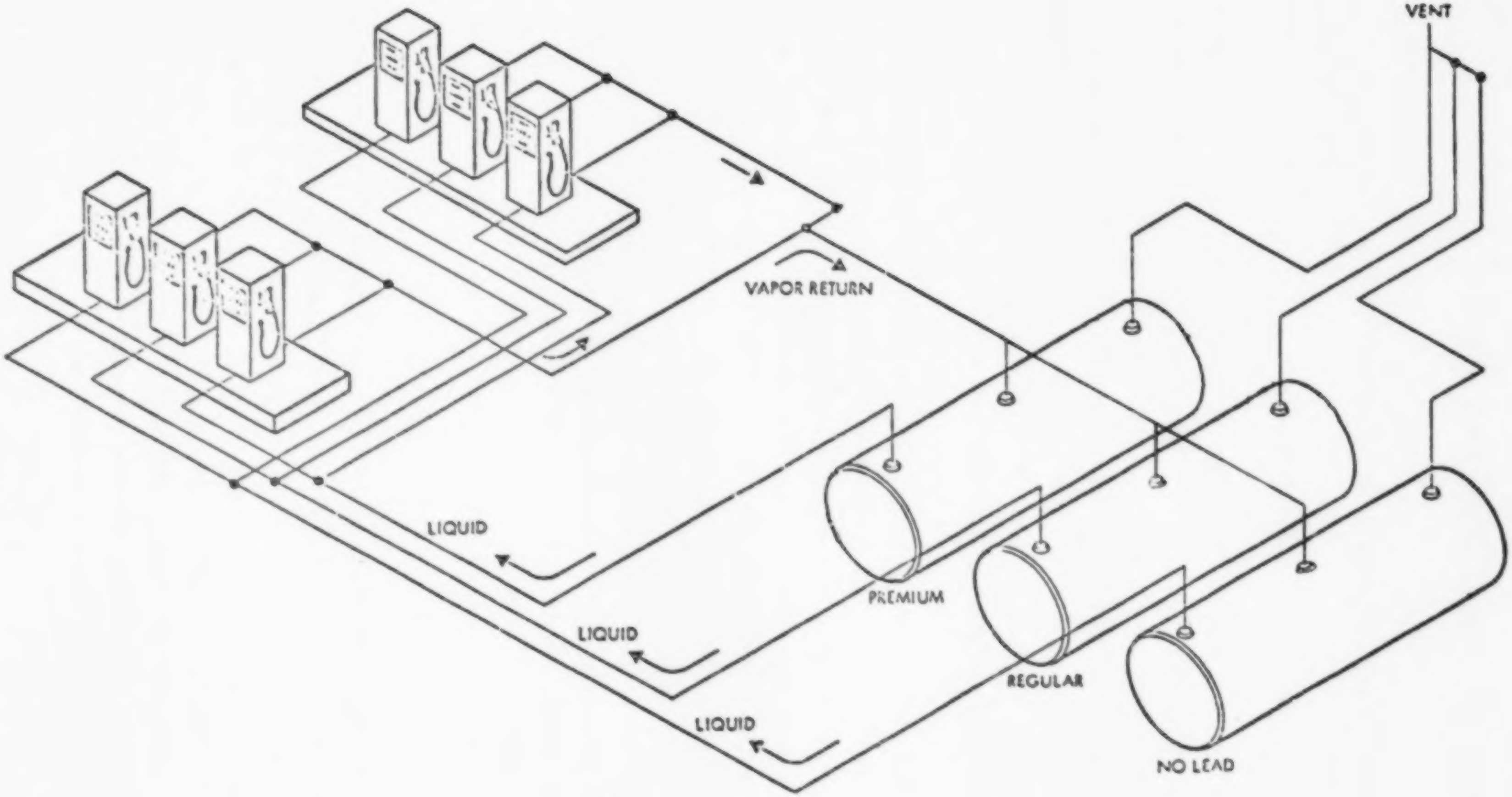
VENT
VAPOR RETURN
LIQUID
LIQUID
LIQUID
PREMIUM
REGULAR
NO LEAD

FIGURE 2.2-22. DIAGRAM OF A VAPOR BALANCE SYSTEM

2.2.2.2 Stage II Control Technology (Cont.)

Vapor Growth in Balance Systems

The operation of the displacement system includes the phenomena of vapor growth or vapor shrinkage. Vapor growth refers to a situation in which the volume of vapors displaced from a vehicle tank is greater than the volume of dispensed gasoline. When the volume displaced is less than the volume dispensed, it is called vapor shrinkage. Vapor growth results in outbreathing of hydrocarbon vapors from the underground tank vent line while vapor shrinkage produces inbreathing followed by partial saturation, expansion, and possible outbreathing. In each case it is assumed that there are no leaks at the nozzle-fill neck interface.

The degree of vapor growth is determined in part by the relative temperatures and volatilities (RVP's) of the dispensed fuel and residual fuel in the vehicle tank. Dispensing cool gasoline into a warm tank or dispensing low RVP fuel into a tank containing higher RVP fuel causes vapor shrinkage while the reverse conditions cause growth.

Of these two effects, the temperature gradient appears to have the greatest impact on vapor growth. EPA source testing has indicated that there is little difference in the RVP's of dispensed gasoline and gasoline in the vehicle tank. Temperature differences (vehicle tank temperature minus dispensed fuel temperature), however, may vary from a ΔT of -25 to +25. Figure 2.2-23, which is based on measured values, shows the effect of RVP on hydrocarbon losses. Figure 2.2-24, which is based on calculated values, assuming equilibrium between the displaced vapor and dispensed fuel, illustrates how the temperature gradient affects the amount of hydrocarbon emissions.

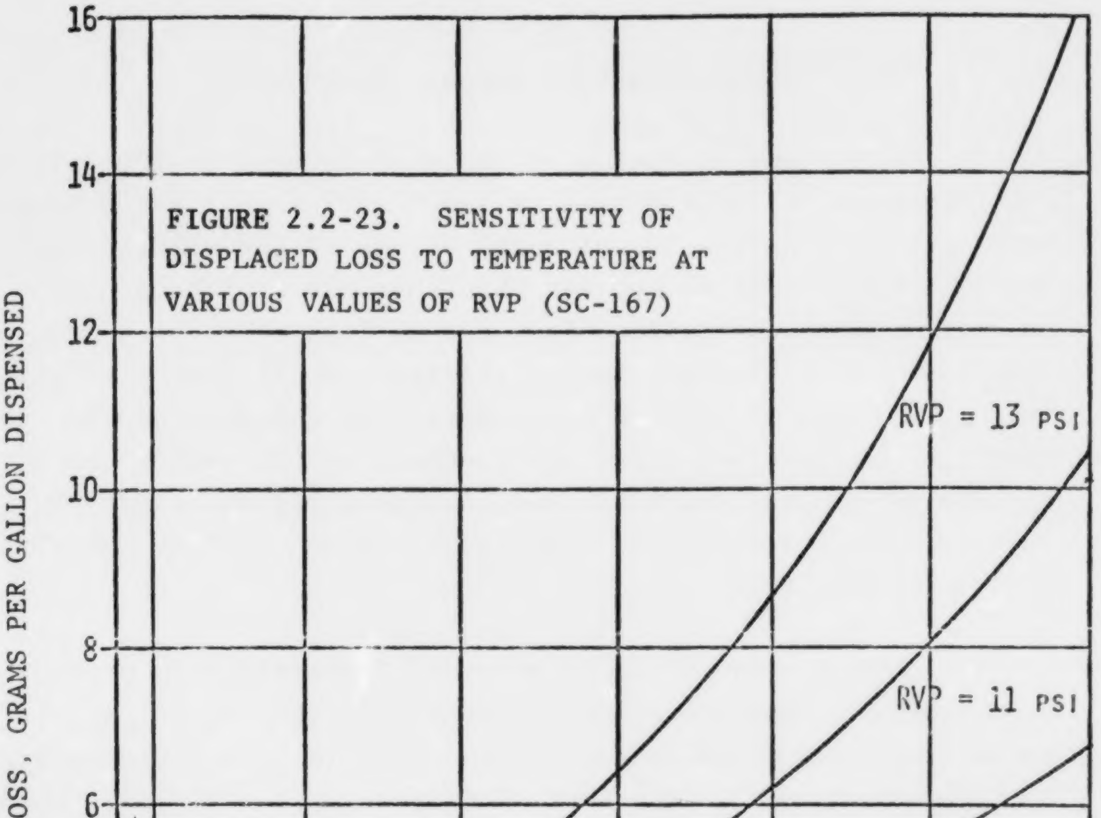

FIGURE 2.2-23. SENSITIVITY OF DISPLACED LOSS TO TEMPERATURE AT VARIOUS VALUES OF RVP (SC-167)

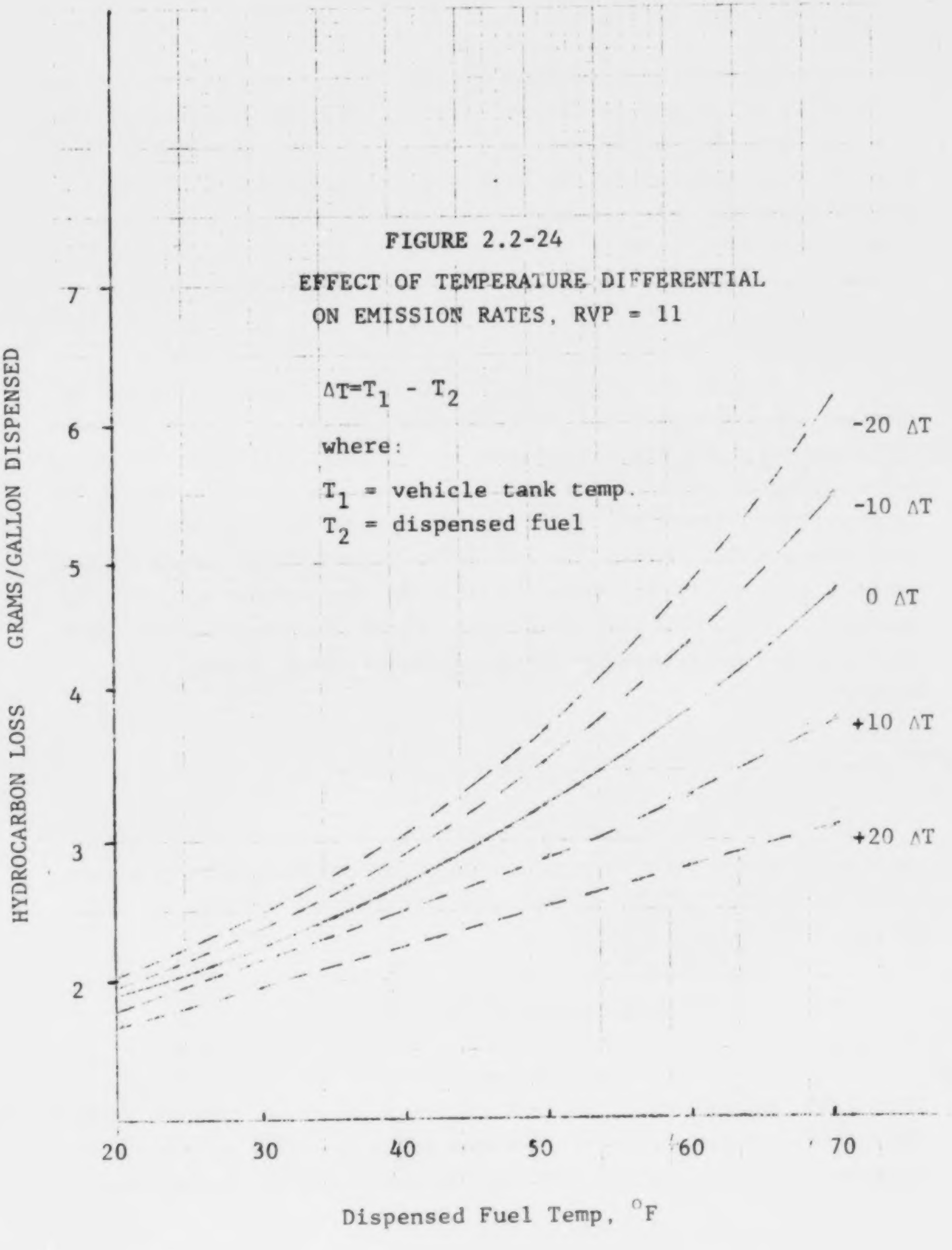

FIGURE 2.2-24

EFFECT OF TEMPERATURE DIFFERENTIAL ON EMISSION RATES, RVP = 11

$\Delta T = T_1 - T_2$

where:

T_1 = vehicle tank temp.

T_2 = dispensed fuel

2.2.2.2 Stage II Control Technology (Cont.)

Other factors which may influence vapor growth are the solubility of oxygen in dispensed gasoline, the fullness of the vehicle tank upon refueling, the amount of fuel dispensed, the rate of fuel dispensing the back pressure caused by the vapor recovery system, and leakage around the fillneck-nozzle interface. Only limited work has been completed at this time in attempts to quantify these effects, although further work is planned.

Source testing performed by EPA on vapor balance systems has confirmed the phenomenon of vapor shrinkage during warm weather. It has been reported but not confirmed that large vapor growths occur during winter conditions (FU-035) resulting mainly from dispensing relatively warm fuel (at say 60°F) to cold vehicle fuel tanks (at say 30°F). It is also possible that vehicle fuel tanks may become heated by the exhaust system during winter driving in which case vapor shrinkage could occur. Further testing is planned to study this effect during cold weather.

EPA - Source Tests

The following paragraphs contain discussions of test results performed with the objective of demonstrating recovery efficiencies of balance systems under a variety of conditions.

Balance System Efficiencies

Source testing performed by EPA in San Diego, June 1974, showed daily percent recovery averages ranging from 62% to 88% at two different balance systems. The only apparent difference in the two systems was in piping which was somewhat

2.2.2.2 Stage II Control Technology (Cont.)

more tortuous at the station with the lower overall average efficiency for the test period (72% versus 82%) (EN-182). Preliminary analysis of source testing data which was also taken by EPA in Hayward and Davis, California, August 1974, showed daily percent recovery averages ranging from 58 to 86 at two different stations. Reasons for the difference in overall average efficiencies (70% versus 84%) have not been fully explained.

The efficiencies reported refer to the difference between actual emissions and baseline emissions. Data from both sets of EPA tests indicate that the baseline emissions average about four grams/gallon. Baseline emissions were determined from those vehicles which had no leaks at the nozzle-fill neck interface and whose tank indicated no leak when submitted to a leak check after the fill. Applying the recovery efficiencies to the baseline emissions results in average hydrocarbon losses for the vapor balance systems of 1.12 gm/gal and 0.72 gm/gal for the two San Diego Systems and 1.2 gm/gal and 0.64 gm/gal for the Bay Area systems.

Test reports presented by several oil companies have shown recovery efficiencies greater than 85%. The higher recovery efficiencies obtained appear to result from greater dilligence by the operator in effecting a seal at the nozzle fill neck interface.

Scott Laboratories - API Tests

Testing performed by Scott Laboratories for the API (SC-186) indicated that recovery efficiencies of 96% (approximately 0.16 gm/gallon loss) were achievable with the balance system when the following criteria are met:

- A leak-free seal is made at the fill neck interface.

- Vehicles being refueled have emission control devices (carbon canisters).

These criteria were met during the study by testing only post-1970 vehicles and by forcing seals at the nozzle-fill neck interface. These tests illustrate the effectiveness of the balance system under good conditions and thus represent actual data on the maximum expected efficiencies.

SHED Tests

Field test data indicate that baseline hydrocarbon emissions from vehicle refueling are 4 gm/gallon. SHED test data (SC-167) indicate that normal uncontrolled hydrocarbon emissions from vehicle refueling operations is 5 gm/gallon. Possible reasons for the 1 gm/gallon difference in the two values may be attributed to the use of vapor recovery nozzles which may restrict hydrocarbon emissions from the fill neck over completely uncontrolled systems and possible leaks through carbon canisters or the vehicle tanks. Further study is required in this area to investigate the difference in emission values.

Likely Emission Sources

Vapors lost from a balance system are currently being lost from either the fill-neck interface or out a vehicle gasoline tank external vent. EPA testing during warm weather has shown zero outbreathing from the underground tank.

External vents are found on two-thirds of pre-1970 vehicles. The other one-third of pre-1970 vehicles vent through the fill neck where capture is possible. The magnitude of the vent loss has been reported to be only six percent of the total vapors displaced from each vehicle (ST-187, PO-100). By 1977, at the current rate of phasing out, there should not be more than 20 percent of pre-1970 vehicles on the road (EN-182) at which time this source of vapor loss will become small.

The majority of reported hydrocarbon losses, therefore, result from a poor seal at the nozzle-fill neck interface. If the problem of leakage around this interface can be solved, the displacement system will then become an efficient and reliable method of recovering vehicle refueling vapors.

There are a multitude of vehicle fill neck configurations and sizes found in vehicles on the road today. It is highly unlikely, therefore, that a single nozzle will be developed to provide leak-free seals on all vehicles. One means of ensuring a tight seal could, however, be through development of fill neck adapters which have been standardized for fill necks on all vehicles. Agreement of automobile manufacturers to supply standardized fill necks with all cars would, of course, greatly simplify implementation of this plan.

Balance System Costs

Service station modification costs, including both equipment and labor have been reported to vary from a low of $5,000 to a high of $8,000 (RE-107, SC-186, EN-184). The low values are based on bid prices and actual installed costs while the high values were based on mid-1974 dollars allowing for recent material escalation. Installation costs for a new service station will be from $2,000 to $3,000 (RE-107, SC-186). Maintenance cost for the displacement system, which mainly involves repairs to the nozzles and hoses has been estimated to be from a low of $30/year (RE-107) to a high of $620/year (SC-186).

Balance System Reliability

Once a vapor balance system is installed and fully leak-tested, simple routine maintenance on the vapor recovery nozzles and hoses should ensure successful operations. The system contains few moving parts and is not dependent on the performance of electrical switch gear. Inefficient operations can be caused, however, by the deterioration of the rubber boots on the nozzles, poor seals at the fill neck interface, and liquid blockage of the vapor return line.

Deterioration of the rubber boot on one of the nozzles used for source testing by EPA during the Bay Area tests was observed after less than one week's operation. Replacement of the boot was a very simple operation taking less than 15 minutes. Frequent replacement of the nozzle boots may be anticipated.

Poor seals at the fill neck interface are to be expected on some cars. Standardized fill necks appear to be one solution, although diligence of the operator in positioning the nozzle on the fill neck is important. Certainly, leaks may occur at any interface if the nozzle is not positioned properly.

It is possible that condensed vapors can collect in the vapor return lines and impede the flow of displaced vapors. Liquid blockage can result in overpressuring of a vehicle fuel tank which may result in gasoline being sprayed from the tank when the nozzle is removed. Liquid blockage of the vapor return line is a potential problem of importance, but one that can be controlled by designing the system to eliminate any pockets in the vapor return hose in which condensed vapors can collect.

Safety Considerations

Implementation of vapor balance systems will result in a decrease of safety hazards over present refueling operations as vehicle refueling vapor emissions will no longer be present around the pumping islands. There is, however, a possibility of overpressuring a vehicle fuel tank during refueling which could ultimately result in the rupture of a vehicle fuel tank. This possibility is, however, remote. A safety relief system in the nozzle would be desirable.

Hydrocarbon leaks may occur in balance systems from unused nozzles with faulty seals, from vapor return connections, from external vents on vehicles, and from poor seals at the nozzle-fill neck interface. Of these leaks only the vapor return connections present a greater hazard than those found with current refueling operations as explosive hydrocarbon mixtures could be released at ground level. Periodic maintenance inspection of the connections, however, should allow for suitable control of these leaks.

(2) Compression-Refrigeration Condensation-Description of System

The major pieces of equipment associated with a compression-refrigeration-condensation (CRC) vapor recovery system are:

- vapor recovery nozzle,
- flexible hose,
- vacuum pumps,
- underground piping system,

- vapor holder,
- two stage compressor, and
- refrigeration heat exchanger.

One commercially available system operates by pumping the collected vapors through a bed of liquid contained within a surge tank where the vapors become saturated. The purpose of the surge tank is to ensure that the vapors are saturated before they are compressed and to even out large volume surges which may occur during bulk drops. The saturated vapors from the vapor holder, or surge tank, are compressed and cooled in a two-stage high pressure refrigeration unit. The condensed gasoline is returned to the underground storage tank and the hydrocarbon-free vapors are vented. Figure 2.2-25 presents a diagram of a compression-refrigeration-condensation vapor recovery system.

A carbon canister can be used in this system in place of the vapor holder and saturator. When the canister is used, all excess vapors pass through it and the hydrocarbons are adsorbed while essentially hydrocarbon-free air exits. The carbon is regnerated by heat assisted vacuum stripping and the recovered vapors are condensed in the CRC unit.

System Efficiency

A system manufacturer claims the recovery efficiency across its process unit to be 94% to 99% with most units averaging 97% recovery. EPA testing of a CRC vapor recovery unit indicated that a processing efficiency of 96% was achievable if there were no leaks in the storage bladder and if all equipment was properly operating. The total system efficiency

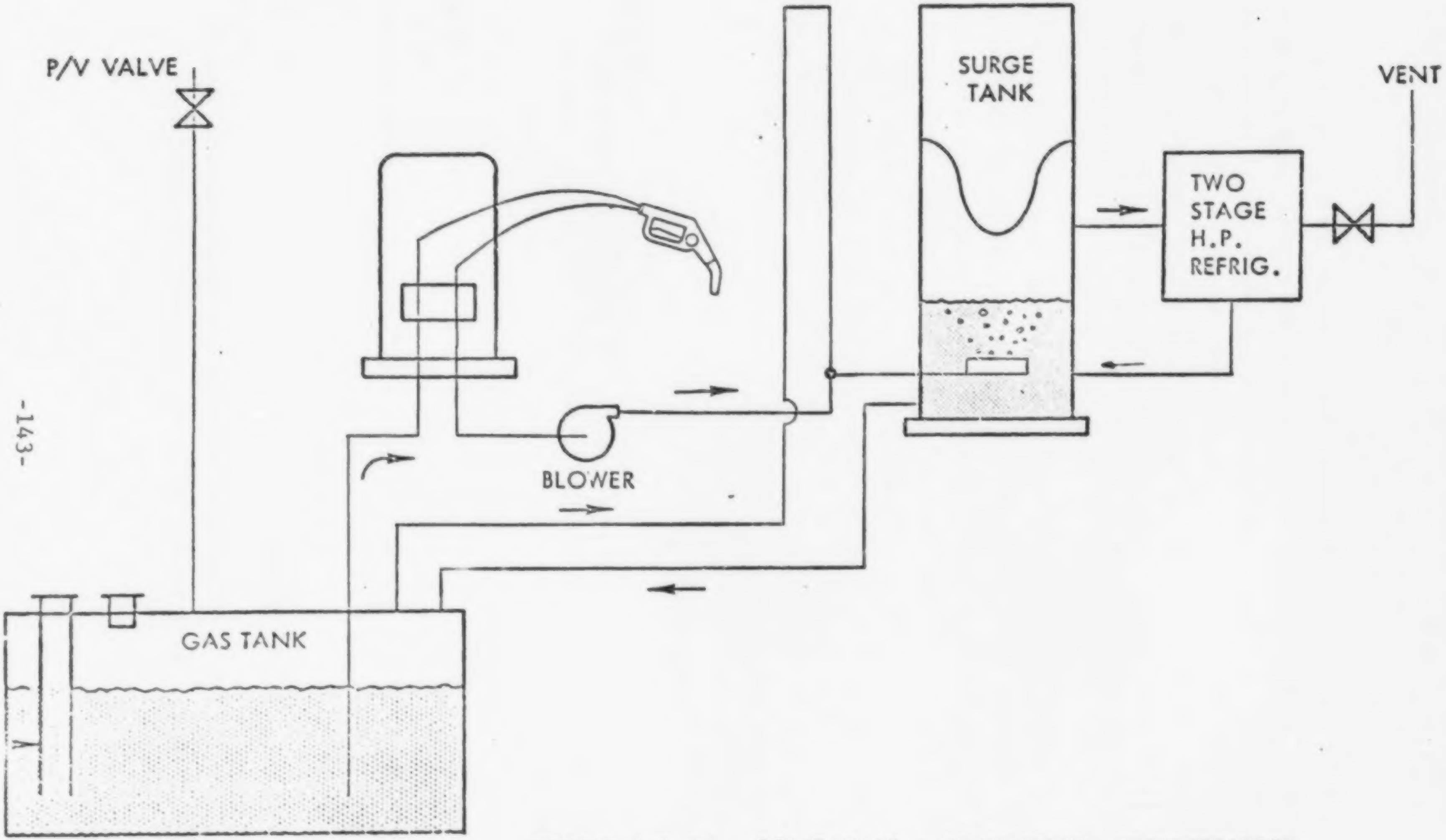
P/V VALVE
SURGE TANK
VENT
TWO STAGE H.P. REFRIG.
BLOWER
GAS TANK

FIGURE 2.2-25. DIAGRAM OF A COMPRESSION-REFRIGERATION-CONDENSATION VAPOR RECOVERY UNIT (HA-256)

could not be determined, however, due to leaks in the system. Hydrocarbon emissions were measured at 9.89 gm/gal compared to mass emissions of about 4 gm/gal normally encountered in balance systems. The vacuum measured at the nozzle during the EPA test ranged from 10 to 15 inches of water. This high vacuum coupled with a relatively good nozzle fit was responsible for the large amounts of vapor pulled out.

Energy consumption values have been reported as 0.25 and 0.37 kwh/day per 1,000 gallons dispensed per month (EN-184). Using the larger value (0.37) still results in a positive energy balance; i.e., the energy recovered (as gasoline) is greater than the energy consumed. Using these values results in an equivalent value of hydrocarbon consumption of 1.12 gal/day and a hydrocarbon recovery of 2.32 gal/day per 1,000 gal per month dispensed. Net equivalent energy recovery is 1.1 gal/day per 1,000 gallons per month (AT-047).

System Costs

The capital cost for a CRC processing unit as reported by a unit manufacturer is $6,000. This price includes only the vapor holder, vacuum blower, and processing unit. Costs of the underground piping system, nozzles and fittings, must be added, which is about $8,000 for retrofitting an existing station and $4,000 for a new station (VI-023). The yearly maintenance and operating costs are reported by a system manufacturer to be approximately 3% of the capital cost.

System Reliability

The manufacturer reports a 0.98 on-stream factor for this system. This means one week per year downtime for preventative maintenance and repairs. Actual CRC operating experience, however, has indicated a much lower on-stream factor.

During an EPA test of this system an exhaust valve froze up causing raw liquid to be discharged from the exhaust vent. It was also determined that the expandable vapor holder bladder was torn, allowing vapors to leak to the atmosphere.

Improvements are still being made on these systems. While reliability is low today, it can be expected to improve with experience and further advances in system design.

Safety Considerations

CRC processing units present several potential safety hazards.

- Explosive conditions in the underground piping caused by introduction of air at the nozzle-fill neck interface.
- Explosive conditions in the vehicle tank caused by pulling in air through an external vent when no liquid is dispensing.
- Leakage of hydrocarbon vapors under high pressure.
- Hazards created by using non-explosion proof electrical system components.

These safety hazards can be eliminated. UL or Factory Mutual certification of packaged systems would certainly eliminate many of them. Presumably explosion proof components will be required for certification. Nozzle modifications to eliminate the accumulation of excess air in the vehicle tanks and at the nozzle-fill neck interface can also be anticipated. Approval of this type system by a certifying laboratory will not only decrease the safety hazards, but will also increase the performance reliability.

(3) Carbon Adsorption

Description of System

Hydrocarbon vapors emitted from vehicle refueling are collected by a vacuum blower and returned via a vapor manifold to the underground tank dispensing the fuel. Excess vapors are displaced through the vapor manifold to carbon canisters. These canisters employ activated carbon to adsorb and store the hydrocarbon vapors.

The canisters would be regenerated offsite (air or vacuum stripping) at a central location where the vapors would be processed. The regeneration cycle time of each canister will depend on many factors, such as gallons throughput, fuel volatility, and canister size. Figure 2.2-26 is a diagram of a carbon storage vapor recovery system.

System Efficiency

The adsorption efficiency of a well maintained carbon adsorption system has been measured as high as 99.7% (LE-132). Assuming a nozzle collection efficiency of 98% (VO-032) and regeneration efficiencies of 90%, 95%, and 98% results in the predicted potential system efficiencies tabulated in Table 2.2-8.

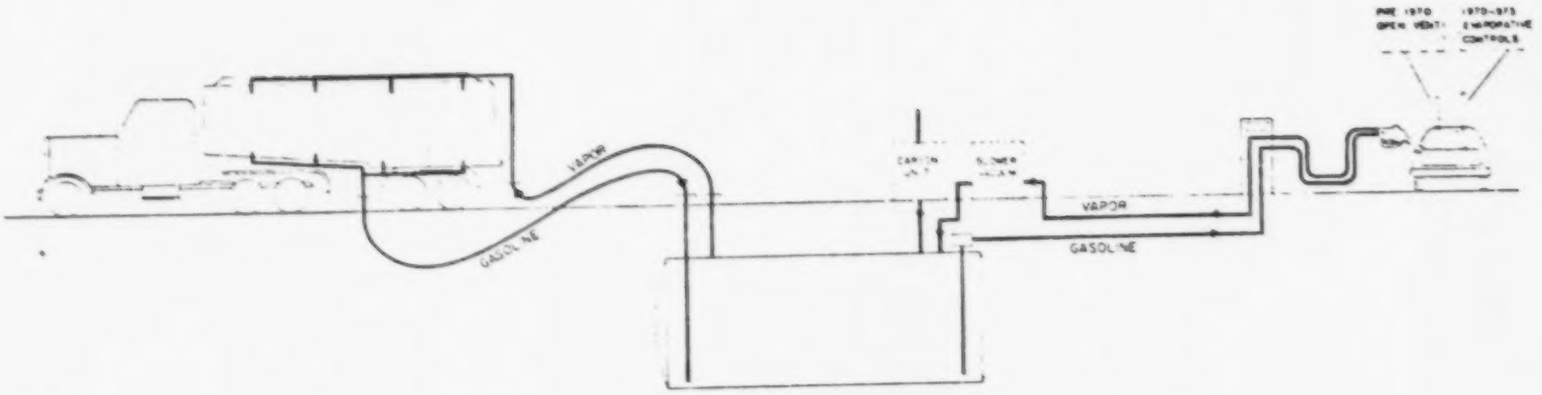
VAPOR
GASOLINE
CARBON UNIT
BLOWER VACUUM
VAPOR
GASOLINE
PRE 1970 OPEN VENT
1970-1973 EVAPORATIVE CONTROLS

FIGURE 2.2-26. SCHEMATIC OF A CARBON STORAGE VAPOR RECOVERY UNIT

TABLE 2.2-8

PREDICTED POTENTIAL EFFICIENCY OF A CARBON STORAGE SYSTEM

Assumed Regeneration Efficiency	Total System Efficiency* Summer	Winter
98	96.5	95.7
95	94.8	92.8
90	91.8	88.0

*Efficiencies for systems not returning a volume of vapors equal to dispensed liquid volume to underground tank would be lower. A vacuum regulating valve would be necessary to maintain the low V/L ratios assumed and to prevent "pullout." (V/L = 1.6 in the summer, 2.0 in the winter). Saturation of excess air due to liquid vaporization in the underground tank was assumed.

System Costs

Installation costs for this system will approach those of a displacement system. Extra costs are for the vacuum blower, carbon canisters, and associated pipe and fittings. Installation costs, including labor, are estimated to be $4,400 for a new station, and $6,900 for a retrofit (RE-107).

System Reliability

Due to its simplicity, the reliability of this system should be relatively high if the system is properly maintained. Potential problems exist, however. For example, a carbon canister may become saturated with hydrocarbon vapors, in which case all collected hydrocarbons will be emitted to the atmosphere. Saturation of the canisters can be avoided by regeneration at the proper time.

Safety Considerations

Explosive mixtures in the vapor recovery piping and vehicle tank are possible hazards with this system. A properly designed nozzle should, however, greatly reduce the probability of these hazards occurring.

(4) Oxidation

Description of System(s)

There are two types of oxidation systems used to eliminate hydrocarbon emissions. They are defined as catalytic oxidation and thermal oxidation processes. Both employ the same basic equipment: vapor recovery nozzles, vacuum blowers, piping systems, excess vapor holders, and an oxidation unit. Both expandable bladder tanks and carbon canisters have been used for vapor holders.

For regeneration of carbon bed vapor holders, a vacuum blower pulls air through the canister in a reverse direction, purging the adsorbed hydrocarbons. The regeneration gases are then passed to the oxidation units. Both the catalytic and thermal units add air to the hydrocarbon stream in a controlled amount to support combustion. After adsorbed hydrocarbons have been removed, the fuel/air mix passing to the oxidation units becomes leaner. The catalytic unit automatically shuts off when the temperature drops below a certain level (say 1100°F) and the thermal oxidation unit is automatically shut off, when combustion is no longer supported. Figures 2.2-27 and 2.2-28 provide diagrams of catalytic and thermal oxidation vapor recovery units.

System Efficiency

A catalytic oxidation unit was tested as part of the EPA source testing program conducted in San Diego. The efficiency across the processing unit itself was measured to be 93.3. The overall processing efficiency, however, was calculated to be 89.4. The low recovery in this case was due to the introduction of a large amount of excess air into the system while operating the nozzle-fill neck interface at a very high vacuum (about 20 inches of water). In addition, relatively poor nozzle fits which were attributed to a rather bulky modification of the regular dispensing nozzle precluded obtaining tight seals on many vehicles. Assuming a nozzle collection efficiency of 98% for the vehicle emissions, an overall system efficiency of 88.1% was achieved.

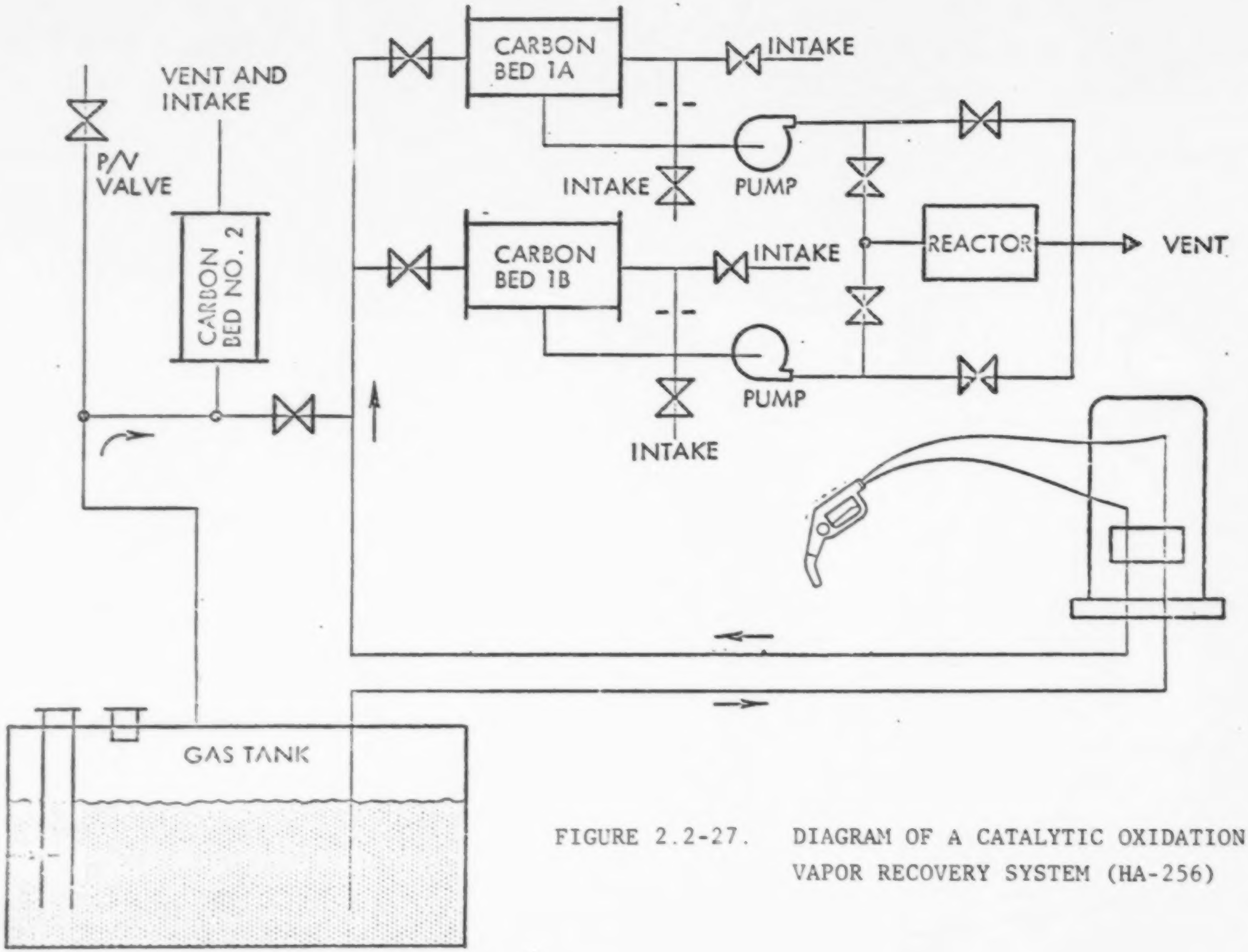
VENT AND
INTAKE
P/V
VALVE
CARBON
BED NO. 2
CARBON
BED 1A
INTAKE
INTAKE
PUMP
CARBON
BED 1B
INTAKE
REACTOR
VENT
PUMP
INTAKE
GAS TANK

FIGURE 2.2-27. DIAGRAM OF A CATALYTIC OXIDATION VAPOR RECOVERY SYSTEM (HA-256)

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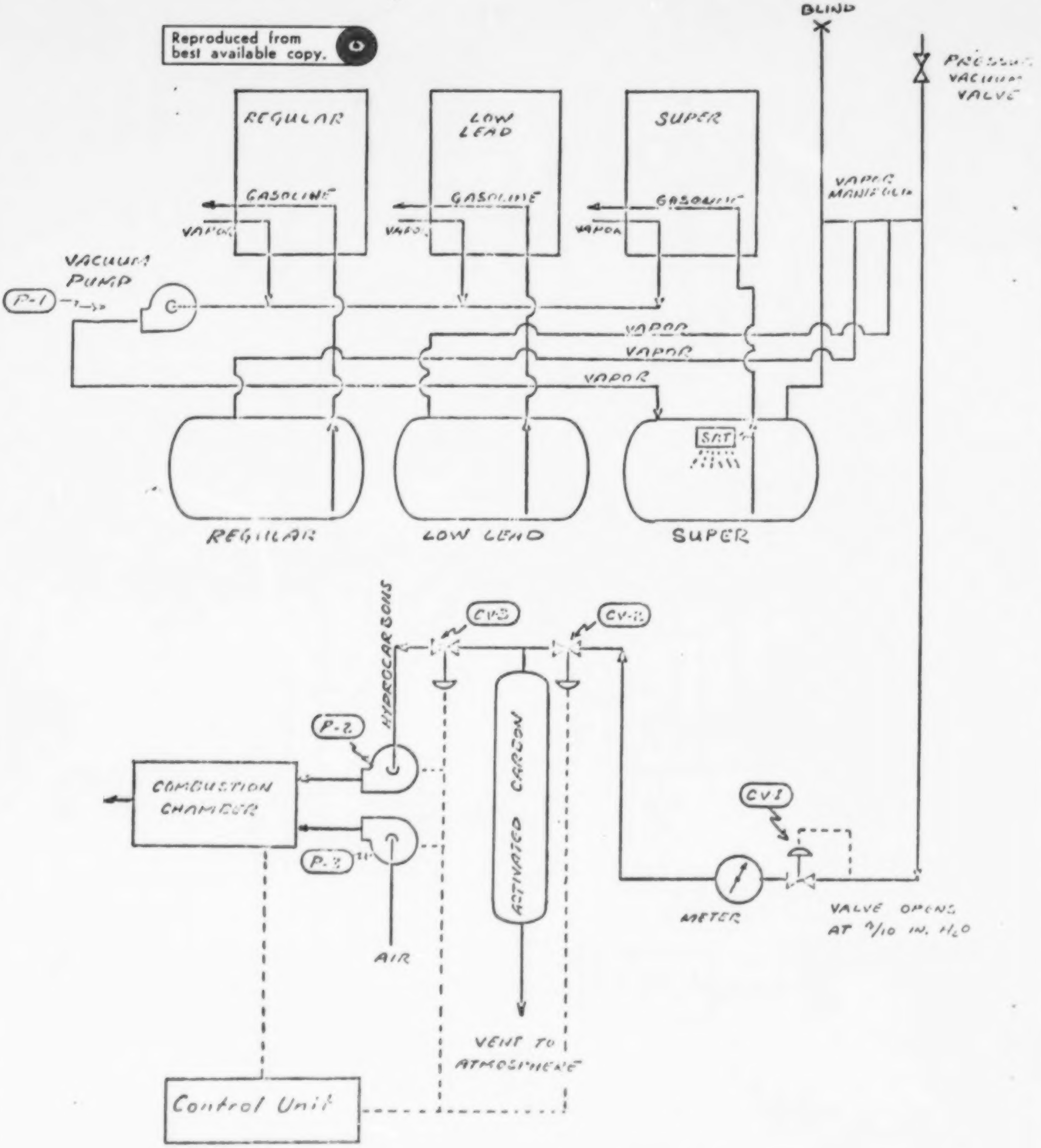

BLIND
PRESSURE VACUUM VALVE
REGULAR
LOW LEAD
SUPER
GASOLINE
GASOLINE
GASOLINE
VAPOR
VAPOR
VAPOR
VAPOR MANIFOLD
VACUUM PUMP
P-1
VAPOR
VAPOR
VAPOR
SAT
REGULAR
LOW LEAD
SUPER
HYDROCARBONS
CV-3
CV-2
P-2
COMBUSTION CHAMBER
P-3
ACTIVATED CARBON
CV-1
AIR
METER
VALVE OPENS AT 2/10 IN. H2O
VENT TO ATMOSPHERE
Control Unit

FIGURE 2.2-28. SCHEMATIC DIAGRAM OF A
THERMAL OXIDATION UNIT

Tests on a thermal oxidation unit have been reported by the Bay Area APCD (LE-132). The efficiency across the processing portion of that unit was 99%. Assuming a vapor liquid return ratio (V/L) of 1.6 for summer operations and 2.0 for winter operations plus a nozzle collection efficiency of 98%, estimated potential efficiencies for this system were 97.1% for summer conditions and 96.5% for winter conditions.

It must be noted that these systems recover none of the vapors adsorbed on the carbon; all collected hydrocarbon are oxidized to CO_2 and H_2O.

Calculations performed by using energy consumption data from an oxidation unit which adsorbed and combusted all collected vapors indicated energy consumption for this system to be 3.83 gal/day per 1,000 gallons per month dispensed (AT-047). Calculations performed by EPA indicated that there would be a net production of energy of 1.06 gal/day per 1,000 gallons per month dispensed if the vapors were returned to the underground tank and only the excess vap were burned. In this case, 20% excess vapors were assumed. Another calculation was performed assuming 40% excess vapors which resulted in a net expected production of energy of 0.16 gal/day per 1,000 gallons dispensed per month. Greater than 40% excess vapors will result in a net consumption of energy.

System Costs

Capital costs reported by a vendor of adsorption-catalytic oxidation unit are shown below.

2.2.2.2 Stage II Control Technology (Cont.)

Station Size gal/mo	Maximum Drop Gallons	Cost ($)
12,000	5,000	3,100
12,000	8,400	3,600
70,000	8,400	4,295
100,000	8,400	5,395

These costs included only the processing equipment. Labor and capital costs of installing the vapor return piping plus the costs of vapor return nozzles and other fittings must be added. These costs range from $5,000 to $8,000 for a retrofit and $3,000 to $5,000 for a new station (VI-023).

Costs were not available for the thermal oxidation system.

System Reliability

The major problem experienced in catalytic oxidation units has been catalyst overheating. When this occurs, the catalyst is usually destroyed. The danger of explosion or fire is also created by this unstable period. Improved fuel-air ratio controllers appear to have greatly minimized this problem, however. During EPA source testing of a catalytic oxidation unit no major operational problems were experienced.

Safety Considerations

The creation of explosive mixtures in the vehicle tank and in the underground piping system is a potential safety hazard with this system. A properly designed vacuum limiting device should, however, greatly reduce the probability of these hazards occurring.

2.2.2.2 Stage II Control Technology (Cont.)

An additional potential hazard in these systems is fire in the combustion section of the units. Flame arrestors should require equipment on these units.

(5) Refrigeration-Adsorption

Description of System

Commercially available refrigeration vapor recovery systems are designed to process the excess vapors from the underground tank. When the system pressure reaches a designated level (say 3" H_2O) the refrigeration unit is activated and vapors are passed across the low temperature cooling coils. This causes some of the excess vapors to be condensed, reducing the volume of uncondensed vapors. Condensed product and contracted vapors are returned to the underground tank.

Under extreme conditions, when large quantities of excess air are suddenly introduced into the system, the system pressure may rise above 3.0" H_2O operating level. When the pressure reaches a maximum of seven inches of water excess vapors vented through a carbon canister which may be regenerated off-line after the system pressure is lowered to its normal operating level. Figure 2.2-29 is the schematic diagram of a refrigeration vapor recovery system.

System Efficiency

Evaluation of the vapor recovery efficiency of a refrigeration system was planned as part of the EPA testing conducted in San Diego. An overall system efficiency could not be determined because of leaks in the underground piping.

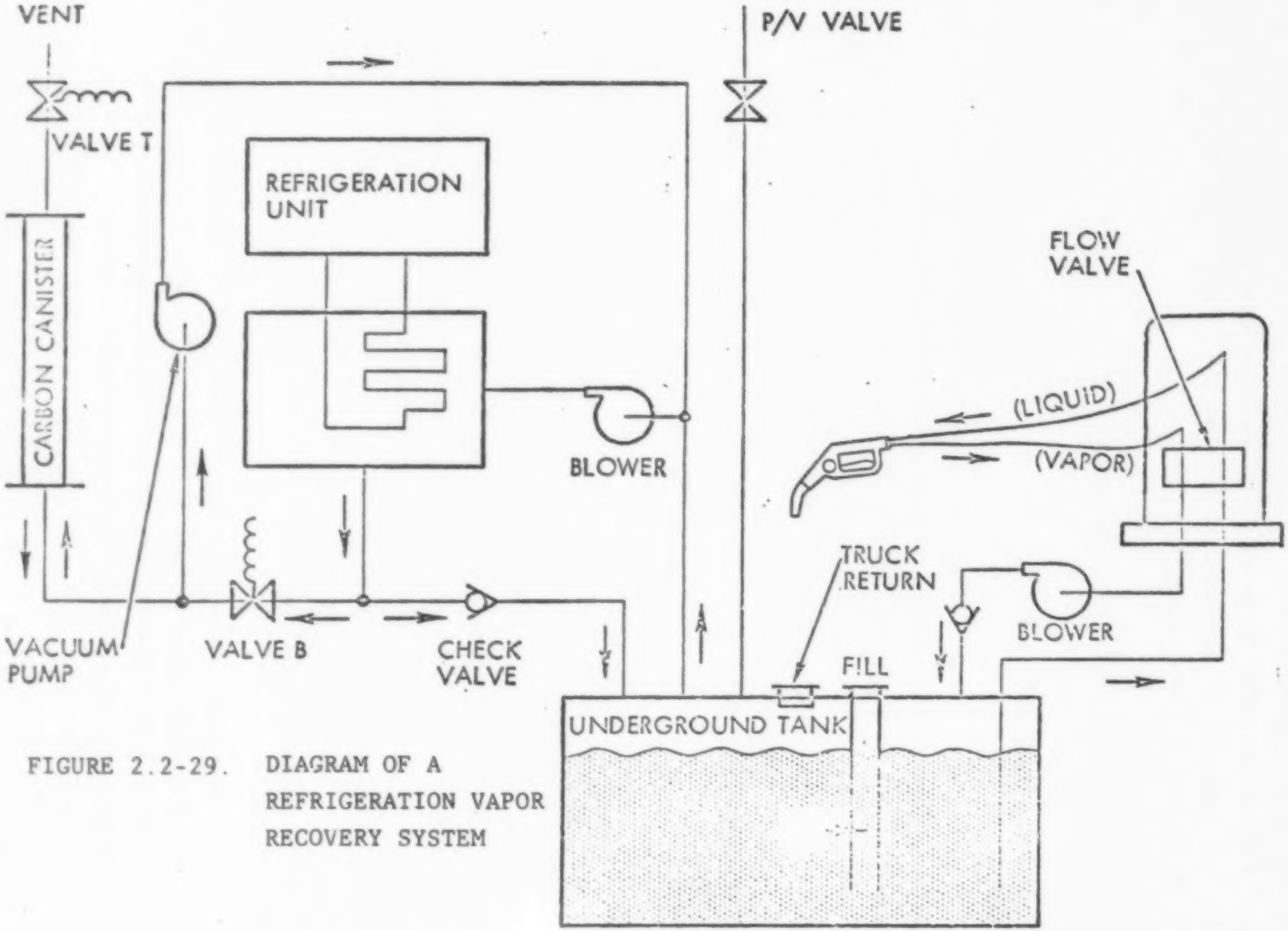

VENT
VALVE T
CARBON CANISTER
VACUUM PUMP
REFRIGERATION UNIT
VALVE B
CHECK VALVE
BLOWER
P/V VALVE
FLOW VALVE
(LIQUID)
(VAPOR)
TRUCK RETURN
FILL
BLOWER
UNDERGROUND TANK

FIGURE 2.2-29. DIAGRAM OF A REFRIGERATION VAPOR RECOVERY SYSTEM

System Costs

Capital costs of a refrigeration unit provided by a manufacturer are listed below.

Service Station Capacity gal/mo	Capital Cost $
10,000	2,500
100,000	3,000
200,000	3,500-3,900

These costs include only the processing unit. Costs of piping including labor must be added to obtain a total system cost.

Total system costs have been estimated at $12,677 for a retrofit and $10,177 for a new station. Yearly operating costs have been estimated at $730 (RE-107).

System Reliability

Refrigeration technology is well established and has been demonstrated to be reliable. The application of this technology to service station vapor recovery should present little or no problems assuming the refrigeration units are given proper maintenance. One manufacturer reports only three days downtime on a unit operating for 1½ years.

Safety Considerations

The creation of explosive mixtures in the vehicle tank, in the underground piping system and at electrical connections are potential safety hazards in this unit. Properly designed nozzles and the use of explosion proof equipment should greatly reduce the magnitude of these hazards.

(6) Gasoline Engine

Description of System

Hydrocarbon vapors are collected from the dispensing nozzle by a vacuum blower and discharged into a vapor manifold. The major portion of the collected vapors are returned to the underground tank dispensing the gasoline. Excess vapors are conveyed either to an activated carbon bed or to the carburetor of a one cylinder, four-cycle engine. The engine and blower are automatically started when the gasoline dispenser is activated. Excess vapors generated at rates greater than the engine can consume bypass the engine and are stored on the carbon bed. The engine is connected to a load blower which simply serves as a sink for energy output.

When the nozzle and blower are cut off the engine continues to operate on hydrocarbons purged from the carbon bed by reversed air flow. When the carbon bed is fully regenerated the engine cuts off from lack of fuel. A special carburetor maintains the fuel air ratio constant. The engine is equipped with a catalytic muffler to oxidize any trace quantities of hydrocarbons or carbon monoxide in the exhaust. Figure 2.2-30 is a schematic of the gasoline vapor recovery system (CL-048).

System Efficiency

Efficiency tests on this system were performed by San Diego APCD test engineers. Their analysis indicated the efficiency of the processing unit to be 95% (CL-048). This high

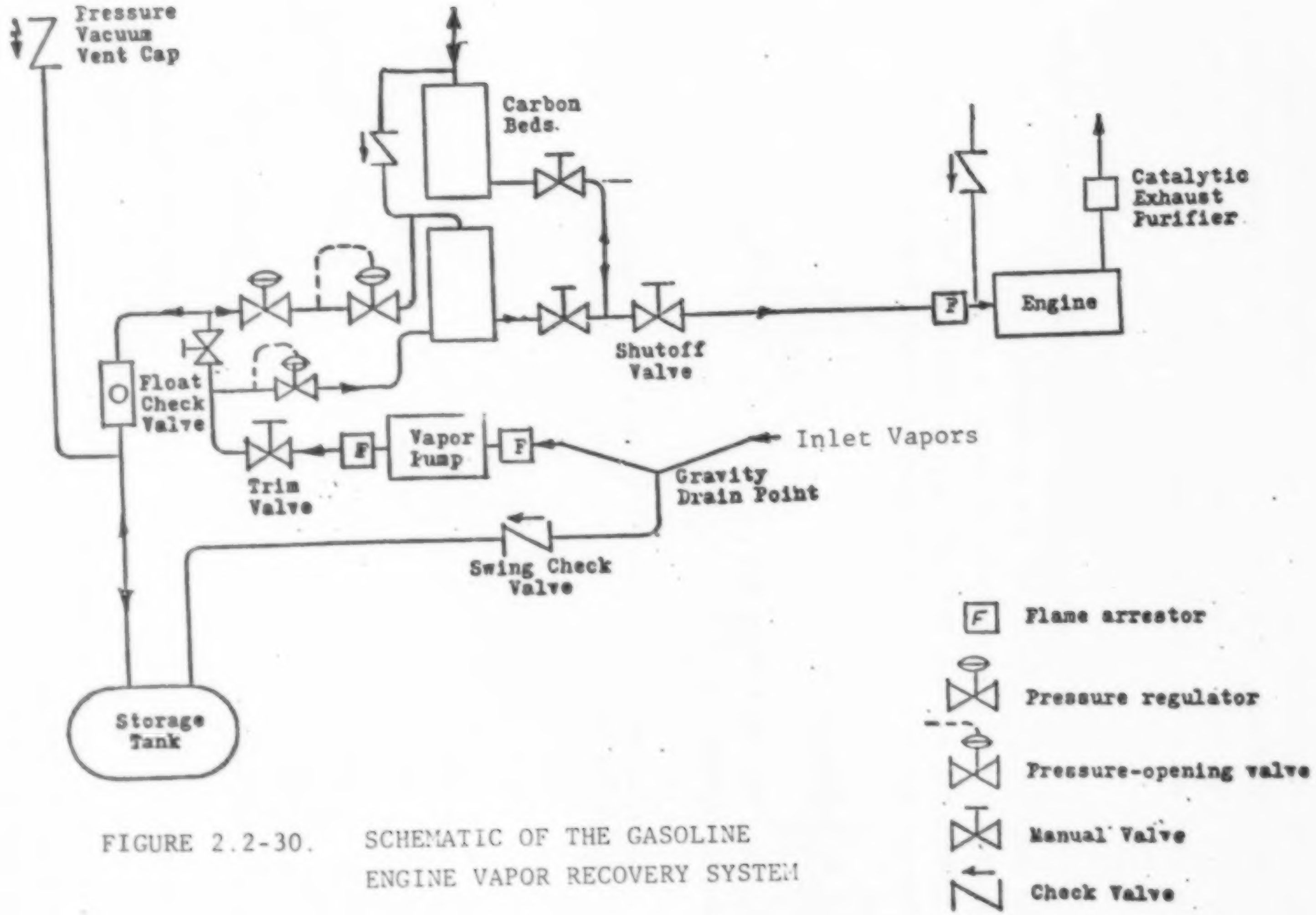

Pressure Vacuum Vent Cap
Carbon Beds.
Catalytic Exhaust Purifier
Engine
F
Shutoff Valve
Float Check Valve
Vapor Pump
F
F
Inlet Vapors
Trim Valve
Gravity Drain Point
Swing Check Valve
Storage Tank
F
Flame arrestor
Pressure regulator
Pressure-opening valve
Manual Valve
Check Valve

FIGURE 2.2-30. SCHEMATIC OF THE GASOLINE ENGINE VAPOR RECOVERY SYSTEM

efficiency is attributed to the complete oxidation in the engine and catalytic muffler. Variations in hydrocarbon concentration entering the recovery system do not affect the system efficiency since the carburetor maintains a constant fuel-air ratio to the engine.

Under present operations (utilization of a load blower) no useful work is performed by the gasoline engine. The load blower serves only to circulate air and to keep a load on the engine. This blower can, of course, be replaced by a generator or compressor which will recover energy produced by the engine.

System Costs

The following costs have been reported by the system manufacturer.

Station Size Gallons/Day	Maximum Drop Gallons	Capital Cost $
500	4,500	2,600
1,000	9,000	3,000
2,500	9,000	3,560
5,000	9,000	4,550
7,500	9,000	5,000
10,000	9,000	-
12,000	9,000	7,500

These system costs include a vacuum blower, carbon bed, engine, full instrumentation and a load blower. Costs of underground piping and vapor recovery nozzles (5,000 to $8,000 for retrofit and $3,000 to $5,000 for new stations) must be added to obtain the total system costs (VI-023).

2.2.2.2 Stage II Control Technology (Cont.)

System Reliability

As of September, 1974 only four of these systems have been delivered, thus little information on reliability is available.

Safety Considerations

Explosive hydrocarbon air mixtures in the vehicle tank and in the vapor recovery piping is a potential hazard with this system. Proper nozzle design should greatly reduce the probability of these hazards occurring.

Vapor ignition from both electrical components and the engine are further potential hazards. Flame arresters and explosion proof components should be employed to control this problem.

(7) Systems Under Development

Several additional recovery units for use in vacuum assist systems are under development. Prototypes of these systems are being tested and commercial units are likely to be in production by 1976. In this section, each of these basic types of systems will be described.

Compression-Absorption-Adsorption

This system operates by compressing hydrocarbon vapors to 22.5 psia and passing them through an absorption column where they are contacted with $0^{\circ}F$ gasoline. Air and unabsorbed hydrocarbons are subsequently vented through a carbon bed cooled by heat exchange with cold gasoline. The carbon bed is vacuum regenerated, with recycling of the desorbed hydrocarbons through the absorption unit. Figure 2.2-31 is a schematic of this type vapor recovery system (EV-013).

The capital cost for this processing unit is projected to be $5,000 for the largest service stations. Installation costs must be added to obtain a total system cost.

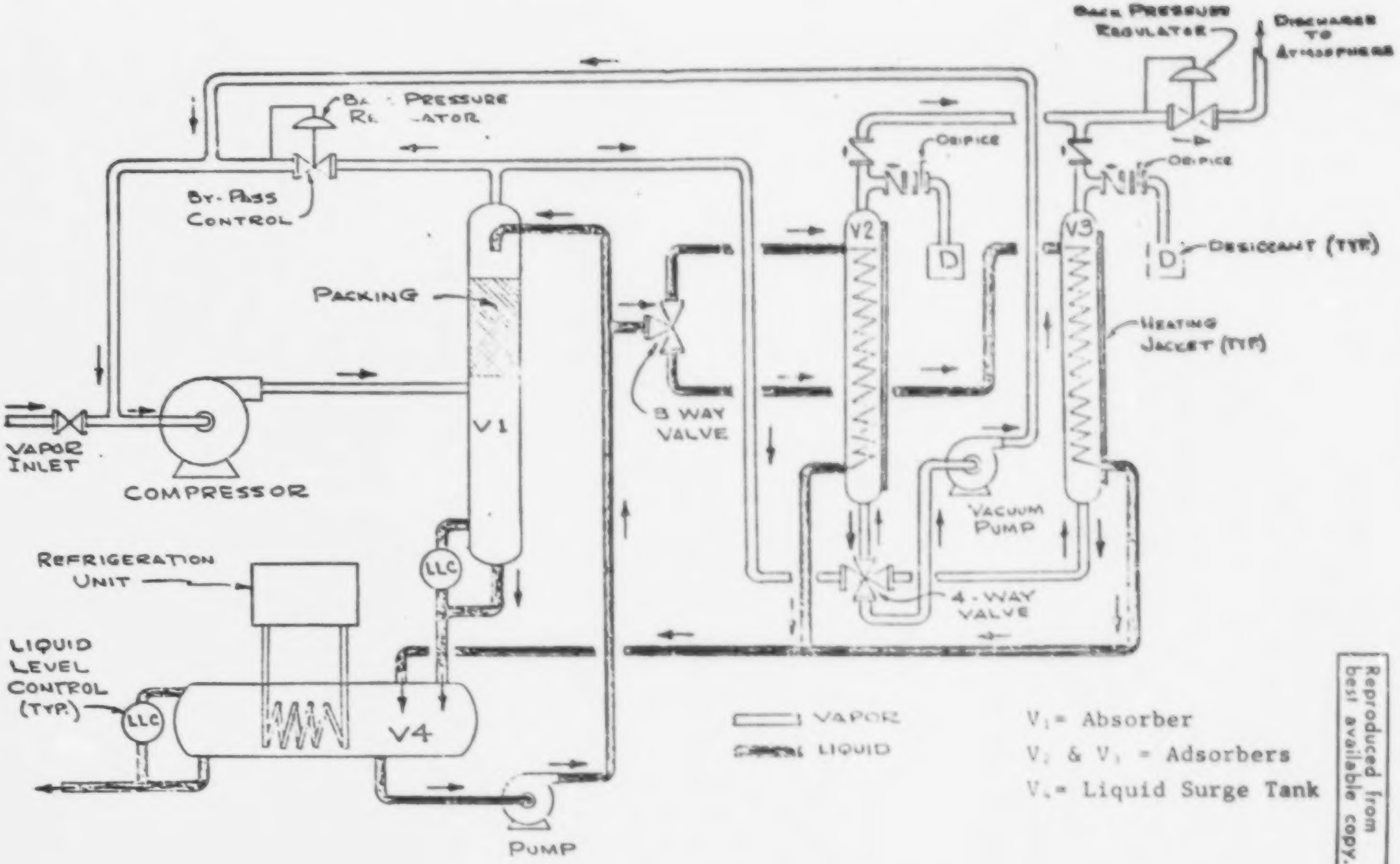
Compression-Refrigeration-Condensation

A CRC system under development offers a new recovery technique. It separates and bottles collected propane and butane products. The collected hydrocarbon vapors are first cooled to 60°F in an exchanger where pentanes and heavier fractions are condensed and returned to the underground product storage tanks. Uncondensed vapors are next compressed to 125 psig and again cooled to 60°F where propanes and butanes are condensed and bottled for sale. The small quantities of methane and ethanes remaining in the vapor stream are adsorbed in a carbon bed and air and unabsorbed hydrocarbons are vented from the bed.

For service stations pumping 35,000 to 90,000 gallons per month, the complete system cost, including nozzles and piping, is estimated to be $8,000.

Open Refrigeration

This system is in design stage only. Hydrocarbon vapors generated during refueling are vacuum collected and returned to the underground product storage tank through a common vapor manifold. Excess vapors are displaced through a refrigeration-condenser unit and cooled to -85°F. The hydrocarbon components of the vapor are condensed out and returned to product storage.


BACK PRESSURE REGULATOR
DISCHARGE TO ATMOSPHERE
BA PRESSURE R ATOR
BY-PASS CONTROL
ORIFICE
ORIFICE
V2
V3
D
D
DESICCANT (TYP)
PACKING
HEATING JACKET (TYP)
3 WAY VALVE
VAPOR INLET
COMPRESSOR
V1
VACUUM PUMP
REFRIGERATION UNIT
LLC
4-WAY VALVE
LIQUID LEVEL CONTROL (TYP.)
LLC
V4
VAPOR
LIQUID
PUMP

V_1= Absorber

V_2 & V_3 = Adsorbers

V_4= Liquid Surge Tank

Reproduced from best available copy.

FIGURE 2.2-31. SCHEMATIC OF A COMPRESSION-ABSORPTION-ADSORPTION VAPOR RECOVERY SYSTEM

Adsorption-Absorption

This system also utilizes on-site regeneration with a carbon adsorption system. Vacuum assist is used to return the collected hydrocarbon vapors to the underground storage tank. Excess vapors are vented through a carbon canister where the hydrocarbon vapors are adsorbed. Regeneration is accomplished by vacuum stripping the off-service carbon canister. The recovered hydrocarbons are returned to the underground storage tank (premium grade) and absorbed into the liquid fuel.

A prototype system has been field tested which demonstrated an overall efficiency of 98.2% including losses from vacuum regeneration. Figure 2.2-32 is a schematic of this prototype system (WA-147).

(8) Summary of Systems

Table 2.2-9 is a summary of efficiency and cost data for each of the vapor recovery systems discussed in this section.

2.2.2.3 Nozzle Design-Effects on Vapor Recovery

Three design parameters appear dominant in the successful operation of a vapor recovery nozzle; the fill neck seal, the pressures created in both the vehicle tank and the vapor recovery system, and the nozzle durability and reliability. Each of these parameters will be discussed individually.

(1) Fill Neck Seal

Due to the wide variety of fill neck sizes, fill neck locations, and the cosmetic treatments of vehicle areas

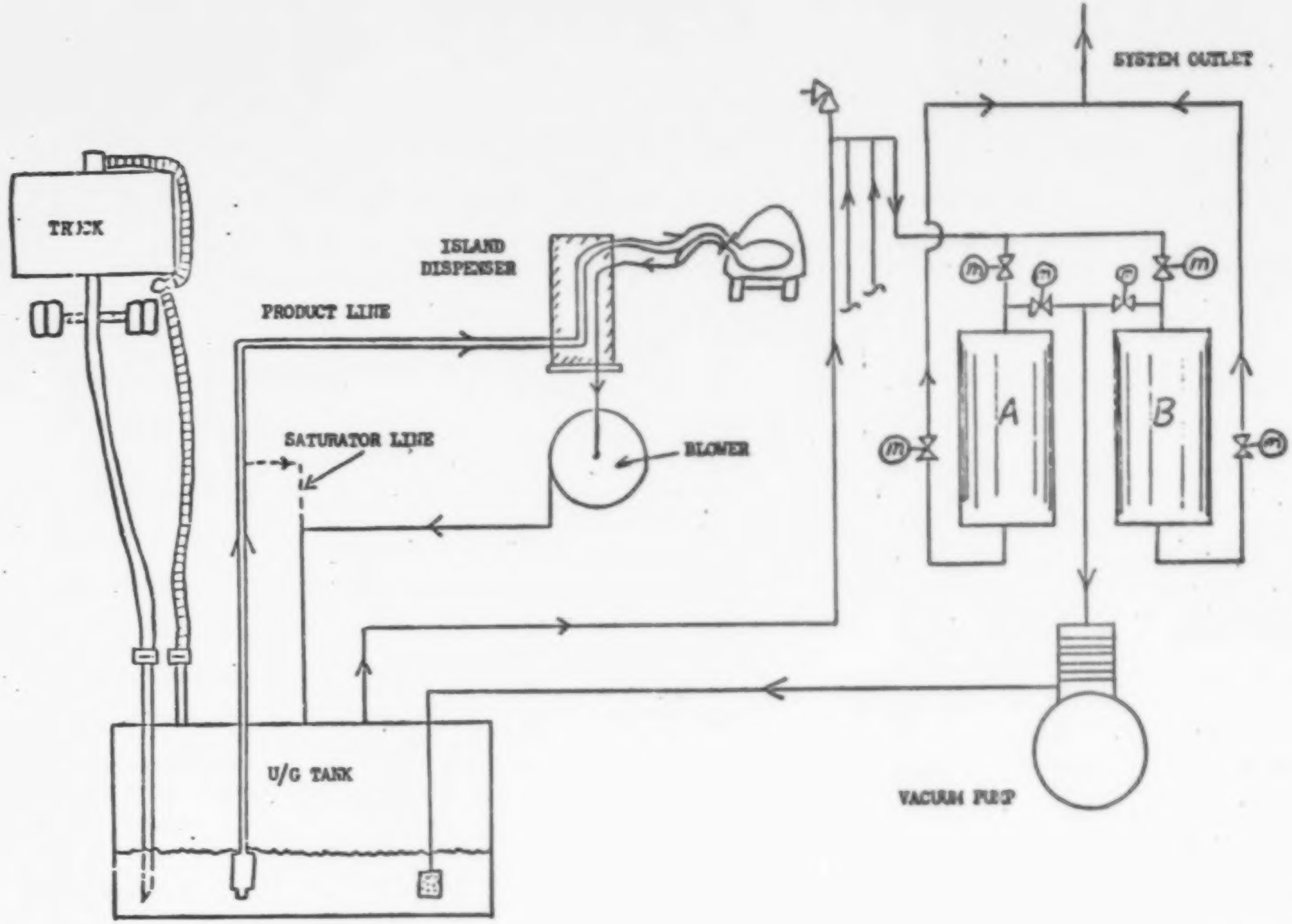

SYSTEM OUTLET
TRUCK
ISLAND DISPENSER
PRODUCT LINE
SATURATOR LINE
BLOWER
A
B
m
U/G TANK
VACUUM PUMP

FIGURE 2.2-32. SCHEMATIC OF AN ADSORPTION-ABSORPTION VAPOR RECOVERY SYSTEM

TABLE 2.2-9

SUMMARY OF SERVICE STATION STAGE II VAPOR RECOVERY SYSTEMS

System Type	Processing Unit Efficiencies (%)	Predicted[1] Total System Efficiencies (%)	Measured[2] Total System Efficiencies (%)	System[3] Cost ($)	Utilities kwh/day per 1000 Gallons Dispensed
Displacement	--	--	70-96	6,000	0
Vacuum Assist					
Compression-Refrigeration-Condensation	97	93		14,000	0.27-0.37
Carbon Adsorption	99	95	----	8,000	----
Thermal Oxidation	99	95	----	-----	----
Catalytic Oxidation	99	95	89.4	13,000	0.68-1.27
Refrigeration Absorption	98	94	----	12,000	----
Gasoline Engine	98	94	----	11,000	----
Compression-Absorption-Adsorption	--	--	----	13,000	----
Open Refrigeration	--	--	----	-----	----
Adsorption Absorption	98	--	----	-----	----

---

1. Predictions are based on the following assumptions: (a) hydrocarbon vapor concentration of 40%, (b) vapor-liquid ratio of 1.6, and (c) nozzle collection efficiency of 98%.
2. Efficiencies from EPA sponsored tests and based on material balances.
3. Vacuum assist costs include installation.

surrounding the fill necks it is unlikely that a single nozzle will be developed that will insure a tight seal on all vehicles on the road today. A leaking seal at the fill neck will generally produce the following effects:

(a) A displacement system will lose hydrocarbon vapors out the leak. The hydrocarbons collected will be less than those displaced and the efficiency will be lower.

(b) A vacuum assist system will pull in excess air through the leak. The volume of air-hydrocarbon mixture to be processed by the secondary control device will range from 20 to 100 percent or more of the volume of liquid dispensed. System efficiencies, if effected, will be lowered.

The effect of a leak at the nozzle-fill neck interface is significantly greater for a displacement system than a vacuum assist system. The vapors lost in a displacement system are unrecoverable; while the excess air introduced into a vacuum assist unit will not significantly affect the operation of many secondary recovery facilities.

To aid in producing a tight interface seal, nozzle manufacturers have incorporated the following concepts: expandable bellows, magnetic disc with flexible boot, hemispherical nosepiece, conical concentric tube, expanded annulus, bell-shaped housing, and ball joint flanges (OL-022). One manufacturer has used modifications to the vehicle fill neck to achieve tight seals on a fleet of test cars. It is conceivable that even further nozzle modifications may be utilized in attempting to obtain a tight seal at the fill-neck interface.

The issue of nozzle design is definitely unresolved. Considerations should be given to requiring standardization of fill necks by the vehicle manufacturers. This could be accomplished with vehicles on the road toady by the use of fill neck adapters.

(2) Reliability

The factors to be considered in assessing the reliability of vapor recovery nozzles are its durability, simplicity, ability to prohibit vapor leaks, and dependability. Simplicity is an important feature for nozzles to be used in self-service operations. The mechanism affecting the seal at the fill neck should be easy to activate and should be effective when hand held.

Nozzle durability is an important function of collection efficiency. As the vapor recovery components (expandable bellows, flexible boots, etc.) start to wear out, significant amounts of vapors may be lost to the atmosphere.

Vapor leaks from unused nozzles are a potential source of hydrocarbon emissions, especially during an underground tank drop. Check valves needed to be designed to prohibit these leaks. Nozzles can also leak in air when not in use. The excess air inbreathed through a nozzle will lower the vapor collection efficiency of a system. Designs should eliminate this source of leaks.

Nozzle dependability refers, in this case, to its automatic shutoff controls. Vapor recovery nozzles, due to their extra components, do not generally extend as far into the fill neck as do conventional nozzles. Consequently, more sensitive automatic shutoff mechanisms may need to be designed to prevent overfills.

(3) Pressure

Vapor recovery nozzles may produce a pressure effect both in the vehicle tank and in the vapor recovery system itself. The driving agent for vapor recovery in a displacement system is a slight negative pressure in the underground piping system coupled with a positive pressure in the vehicle tank. The tank pressure "pushes" the vapors into the underground piping. They are "pulled" into the underground storage tank.

Excess pressure can be built up in the vehicle tank which normally results in gasoline "spitback." Excess pressure in a tank can also interfere with the automatic shutoff mechanism on a nozzle. In an extreme situation, pressures could arise that would rupture a vehicle tank. Vehicle tank pressure build up normally results from blockage of the vapor return line.

An apparently simple and effective means of prohibiting pressure build up is to eliminate traps in the vapor return line where condensed liquid can collect and stop the flow of vapors. Another method is to install a pressure relief system in the nozzle

Maintenance of low resistance in the vapor return line is advantageous to the recovery efficiency. Check valves which are necessary to prevent nozzle leaks can increase the resistance to flow towards the underground storage tank. Care must be taken in their design to prevent excess pressures from occurring. The vapor return line through the nozzle should be an effective 3/4" diameter to help eliminate flow resistance.

U.L. approval of vapor recovery nozzles will probably result in performance specifications for vapor recovery nozzles. Adherence to performance criteria will eventually result in the same type of reliability experienced by non-vapor recovery nozzles.

2.2.3 Bulk Stations

Very few studies have been conducted on bulk station emission controls, however, research on service station and terminal control techniques is largely applicable to bulk stations. The two primary emission sources at bulk stations are transfer operations and tankage. Emissions from transfer operations are attributed to vapors displaced during the filling of bulk station storage tanks and the filling of delivery trucks. Tankage emissions are attributed to diurnal breathing losses. The two basic approaches to controlling these emission sources is straight vapor balance and vapor balance in conjunction with vapor recovery systems.

2.2.3.1 Vapor Balance

The control of transfer losses from bulk stations centers mainly around vapor balance and bottom loading. Converting to bottom loading and reducing transfer rates will tend to reduce the generation of gasoline vapors. In Section 2.2.2.1 (Stage I Controls) it is reported that vapor balance systems at service stations fuel drops achieve an average emission reduction efficiency of 95% to 96%, with very few efficiencies falling below 90%. The same efficiency should be possible when applying that system to bulk station transfer losses.

Bulk station storage tanks are usually truck portable horizontal or vertical tanks. It is uneconomical to install variable volume vapor storage or floating covers on these tanks to control breathing losses. One economical solution to breathing losses is the installation of pressure-vacuum vents on the tanks. Figure 2.2-33 (NI-027) indicates that tankage breathing losses can be virtually eliminated by using a P-V vent with a 40 oz/in^2 (2.5 psig) pressure setting and a reduction of 70% can be achieved by using a P-V vent with a 16 oz/in^2 (1 psig) pressure setting. Since API tankage is already stressed for higher working pressures than these, additional tankage costs would not be incurred.

As pointed out in Section 3.9, air is soluble in gasoline. The gasoline delivered to bulk stations should be subsaturated with respect to air. Because of this it is expected that some vapor shrinkage will occur within the tankage as air is absorbed from the vapor space. This shrinkage further enhances the efficiency of the balance system.

2.2.3.2 Vapor Recovery Systems

If the efficiency of the balance system proves insufficient, bulk stations can be equipped with vapor recovery systems. The vapor recovery systems would be installed in conjunction with balance systems piping to process only the excess vapors which the balance system fails to control. Large bulk stations would employ one of the terminal size vapor recovery systems outlined in Section 2.2.1, for terminals, and a small bulk station would employ one of the service station size vapor secondary recovery systems outlined in Section 2.2.2.

2.2.3.3. Cost

No data is available on the cost of installing a balance system in a new bulk station er on the cost of retrofitting

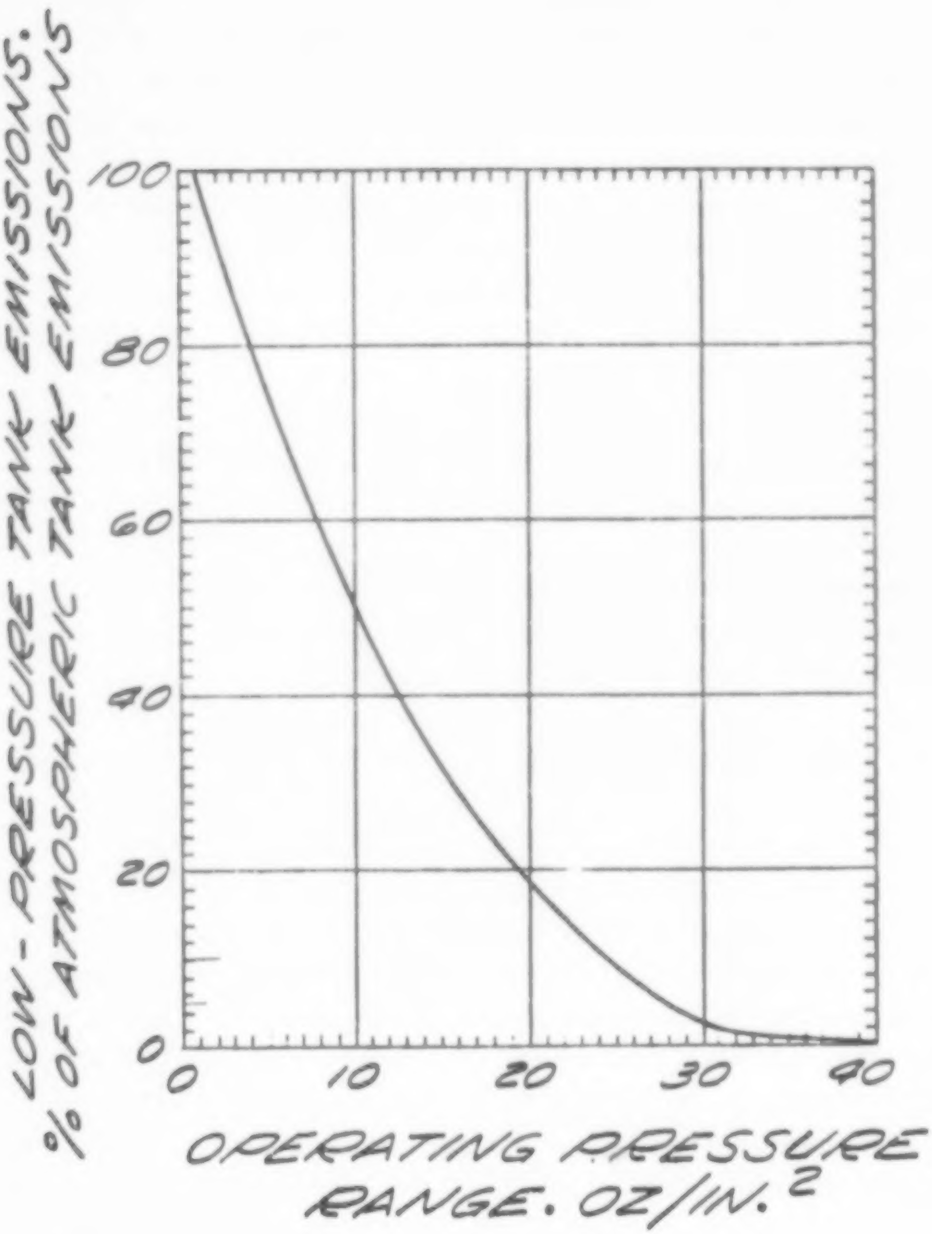


FIGURE 2.2-33. LOW PRESSURE TANK EMISSIONS VS TANK OPERATING PRESSURE RANGE

existing bulk stations with the balance system. Costs for terminal vapor recovery systems and for service station vapor recovery systems are presented in Sections 2.2.1 and 2.2.2, respectively.

2.2.3.4 Operating Reliability

The operating reliability of the balance system is very high. It is simple with very few parts to fail. Vapor recovery systems on the other hand are constructed of complex equipment and are therefore more subject to failures. Considering the sophistication of vapor recovery equipment, the lack of motivation at bulk stations to maintain non-profitable equipment, and the fact that bulk stations are often situated in areas remote to repair services, the vapor balance portion is significantly more reliable than the secondary recovery portion of the systems described above.

2.3 Other Environmental Effects

2.3.1 Impact on Water Pollution

The control of air pollution from gasoline marketing facilities need not adversely affect water pollution problems at all. Liquid hydrocarbons removed in terminal secondary recovery units can be recycled directly to fuel storage. Incidence of spillage and runoff to water collection systems is likely to be lowered in recovery units than in primary gasoline handling and storage areas.

2.3.2 Impact on Solid Wastes

In all cases, gasoline handling involves liquid and, to a lesser degree, vapor phases. There are no naturally occurring solids, nor are there chemical reactions that will tend to form and precipitate solids. While gasoline liquid discharged to the sewer can have solvent action on many solids and liquids, this does not in itself promise to have an impact on solid wastes.

2.3.3 Energy Considerations

There are two aspects of energy usage in vapor recovery units. One is net conservation because of recovered liquid fuel. The other is energy (primarily electrical) consumed in operation of secondary recovery units.

Table 2.3-1 contains a summary of relative energy conserved or spent at marketing locations for various typical vapor recoveries. Overall, the energy value of fuel recovered far outweighs energy consumed in recovery. For a typical service station handling 25,000 gallons per month gasoline recoveries in the order of 700 gallons per year from the tank trucks and terminal and 300 to 400 gallons per year refueling can be realized at the anticipated control levels.

2.4 Advantages/Disadvantages of Various Regulation Criteria

There are three regulation types which may be implemented for hydrocarbon vapor emission controls. They are:

(1) a percent reduction regulation,

(2) a mass emission regulation, and

(3) an equipment standard regulation.

The relative advantages/disadvantages of each regulation type will be discussed in this section.

2.4.1 Regulations Based on Percent Reduction

Regulations based on a percent reduction criteria will require rigorous monitoring procedures to evaluate compliance. Monitoring procedures must be designed to determine the amount of vapors emitted to the atmosphere under both controlled and non-controlled conditions so that a percent reduction can be calculated.

TABLE 2.3-1
ENERGY CONSERVED OR USED AT GASOLINE MARKETING FACILITIES

	Emissions			Equivalent Energy Btu/1000 gal	
	Uncontrolled(1) gal/1000 gal	Controlled gal/1000 gal	% Recovery	Recovered(2)	Expended
Bulk Terminals	1.10	0.11	90	120,000	20,400(3)
Service Stations					
loading & breathing	1.61	0.15	95	175,000	0(4)
refueling (assist)	1.44	0.13	90	157,000	153,000(3)
refueling (balance)	1.44	0.26	80	142,000	0(4)

(1) Estimated (EN-071)

(2) Assumed 120,000 Btu per gallon fuel value.

(3) Based on using 2 kwhrs/1000 gallons handled to operate an open refrigeration system to recover displaced vapor from terminals. It was assumed 15 kwhrs/1000 gallons are consumed in operating a compression-refrigeration-condensation secondary recovery units to recover losses from the refueling step. It was assumed that electrical power was generated with a 33 percent efficiency on fuel fired at the generating station.

(4) Based on using a vapor balance system with bottom loading for fuel drops and storage and secure nozzle fit at the fill pipe.

2.4.1 Regulations Based on Percent Reduction (cont.)

Regulations based on this criteria will require a vapor recovery system which will produce less emissions during the winter season than the summer season for a given percentage recovery. This is because the non-controlled emissions tend to be greater during the hotter months.

The percent reduction regulation has one advantage. Monitoring procedures can provide data to support detailed material balance calculations. The results of these calculations can aid in detecting leaks in the vapor recovery system. A regulation of this type would be applicable to all systems in the gasoline marketing network.

The major problem in evaluating the percent reduction of hydrocarbon emissions from a bulk terminal is involved in measurement of the vapors displaced from the truck as it is filled. If three products are loaded simultaneously, the vapor displacement rate can approach 270 CFM. Instruments capable of measuring such a high of a flow rate are not readily available. They are also quite expensive.

The percentage reduction of hydrocarbon vapors resulting from underground tank filling operations could require that all vapors being emitted from the underground tank to both the truck and the underground tank vent line be monitored. For recent test procedures, it has been assumed that the vapor to liquid ratio is 1:1 and only the excess vapors emitted from the underground tank vent have been measured. This is because monitoring vapors returned to the truck is a difficult measurement.

2.4.1 Regulations Based on Percent Reduction (cont.)

Service station vehicle refueling operations present the largest monitoring problem. For both vapor balance systems and vacuum assist systems no monitoring procedure has yet been agreed upon. In order to determine the percent reduction of emissions, uncontrolled emissions must first be defined and methods for doing this have not been developed.

Questions arise as to the type of test procedure to be used in evaluating uncontrolled emissions, and whether or not the uncontrolled emissions will be evaluated on an average or a car-to-car basis. These questions must be resolved before this type of regulation can be enforced.

2.4.2 Regulations Based on Mass Emissions

Regulations based on a mass emission criteria will require a less complicated monitoring procedure than a regulation based on percent reduction. This is because only the vapors emitted to the atmosphere need be monitored to evaluate compliance. This assumes, of course, that the system being monitored has no leaks and that all vapors being emitted to the atmosphere are being emitted at the location of the monitoring equipment.

Seasonal operations will not affect a regulation based on a mass emission. This is an advantage in that lower emission levels will not be required during the winter months when oxidant levels are low. Regulations based on this criteria would be applicable to all systems in the gasoline marketing network.

Monitoring bulk terminals for mass emissions can be relatively simple if it is assumed all displaced vapors are captured and that the system is leak-free. The off-gas from the secondary recovery unit would simply be monitored for quantity and hydrocarbon concentration.

2.4.2 Regulations Based on Mass Emissions (cont.)

An examination of test data taken at various bulk terminals has indicated, however, that leaks in the transport trucks may be a significant source of hydrocarbon emissions. Because of this, complete material balance data may be necessary to evaluate compliance with mass emission regulations for bulk terminals.

Service station underground tank filling operations would be evaluated by monitoring only the excess hydrocarbon vapors emitted from the tank vent during filling operations. Again, an assumption of leak-free transfer operations must be made. All vapor connections can be checked with an explosimeter, however, to verify the system is leak-free.

Mass emissions from vehicle refueling operations may be easily determined for a vacuum assist recovery system by measuring the hydrocarbon emissions from the exhaust line of the secondary recovery unit. This assumes there is no leakage from the nozzle-fill neck interface, an assumption that can be challenged. There is currently no common method of determining the quantity of emissions from the nozzle-fill neck interface for vacuum assist systems.

The major source of hydrocarbon emissions from a vapor balance system is through leakage at the nozzle-fill neck interface. Monitoring methods to determine the quantity of these leaks are currently being evaluated. If and when a "tight seal" nozzle is developed, mass emissions may be determined by simply monitoring the underground tank vent vapors.

2.4.3 Regulations Based on Equipment Standards

The main advantage to a regulation based on equipment standards is the virtual elimination of compliance monitoring. Compliance could be achieved through only periodic inspections of vapor recovery facilities to check equipment for proper operation. Detailed designs of each system would, however, probably need to be approved by regulatory personnel.

Equipment specifications for secondary recovery systems would not be practical due to the variety of processing operations which may be employed in the recovery of hydrocarbon vapors. A regulation of this type would, therefore, not be practical as a method of controlling emissions from bulk terminals and service stations employing vacuum assist recovery systems.

Regulations based on equipment specifications can, however, be an effective method of controlling hydrocarbon emissions from vehicle refueling operations when a vapor balance recovery system is employed and from underground tank filling operations. In both cases, vapor recovery operations consist primarily of containing the displaced vapors. Neither operation employs processing equipment to recover vapors on-site; only vapor connectors and transfer piping are used in the recovery operations. Equipment specifications for these connectors and piping is feasible as a method of insuring that a system will be capable of collecting the vapors in a proper manner.

Leak tests should be performed on these systems. Once a system is leak-free, periodic inspections of the equipment should be satisfactory for assuring its proper operation.

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